Design of Vineyard Irrigation System and Reservoir Enlargement

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First, I would like to thank my family and friends. They never let me stray from my goal of a higher education and because of them, I’m finishing up this December. Second, I would like to thank every BioResource and Agricultural Engineering professor in the department. They made me feel right at home from the minute I arrived and continuously confirmed that this major was the right place for me. Third, I would like to thank Dr. Howes, my advisor, for helping me along the way with this project.
ABSTRACT

The goal of this project is to design a drip irrigation system for a 25 acre vineyard in Potter Valley, Ca. This allows water to be efficiently delivered to the plants in a timely manner in order to maximize yield or fruit quality. This design will also include the resizing of the current reservoir in order to accommodate for the new water requirements; however this design will not include the overhead sprinkler system needed for frost protection.
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INTRODUCTION

A huge issue that agricultural engineers will face in their careers is the decline in available water for both municipal use and agricultural use. This affects just about everyone because we need water for both in house use and for growing the huge percentages of the nation’s crops here in California. This sets the table for a much more efficient use of the water that we can get our hands on and having to deal with less. On a farmer’s standpoint, these rising water costs and power costs encourage them to put in better or more efficient irrigation systems and invest in more efficient pumps with variable frequency drives. These newer more efficient irrigation systems allow the farmer to do more with less. They have less labor costs/needs, pumping costs and some even have the capability of being run automatically or over the internet. Not only does this translate into water savings but energy savings as well.

Dan Todd has been farming in Potter Valley, Ca since his dad moved there in early 1960’s. They started by dabbling in the vegetable crops and grass hay but eventually converted most of their land into pears. Today Dan farms roughly 70 acres of Bartlett pears and 15 more acres of organic Bartlett pears in addition to the 25 acre vineyard he is going to put in. The current water delivery system used is flood irrigation in the form or border strips but Dan wants to equip his new vineyard with drip irrigation. The water supply being used is both from irrigation district turnouts with booster pumps, well pumps and small reservoirs. Dan also uses under tree sprinklers and elevated fans for frost protection. In addition to Dan being a longtime Potter Valley local, he is a very close family friend and the vineyard he is putting is across the street from my parent’s house: see Figure 1 below.

Figure 1: Field picture with reference to my parent’s house.
The scope of this project is to supply Dan Todd with a well planned and designed drip irrigation system for his future vineyard. In addition to the irrigation design, the reservoir seen in Figure 1 will also need to be enlarged and will be covered in this project. On the other hand the solid set sprinkler system needed for frost protection will not be included in this project. The main components of the design will be underground to allow for machinery access and some protection from freezing pipes. A filter station at the head of the system will be incorporated and properly sized along with the pumping requirement for the whole field’s irrigation need. This will not however include the pumping requirement for the frost protection system. Once the design is completed it will be analyzed and then presented to the client, Dan Todd.
LITERATURE REVIEW

Due to the unfamiliarity with most people and the terms often used in the irrigation industry, a literature review has been performed to define certain terms, see what information was already out there and what needs to be taken into account for this project.

Efficiency

Efficiency can be looked at in two different ways: irrigation efficiency (IE) and application efficiency (AE).

Irrigation efficiency, the more popular of the two terms, is defined as the “irrigation water beneficially used” divided by the “irrigation water applied minus the irrigation water stored” (Burt, 2012). More frequently the equation is simplified to the “irrigation water beneficially used” divided by “the irrigation water applied.” In equation form:

\[
IE = \frac{\text{Irrigation Water Beneficially Used}}{\text{Irrigation Water Applied} - \text{Irrigation Water Stored}} \times 100
\]

This “irrigation water stored” part of the first equation can be taken out for the simplification because in most cases the efficiency is being analyzed on an on-farm basis and there is typically no change in storage. The tricky term in the above equations is the word “beneficial.” Beneficial use of the water is referring to crop evapotranspiration (evaporation and transpiration), salt leaching or other special purposes such as pre-irrigation, soil preparation, weed germination and climate control (Burt, 1995). Water can be stored in the root zone but if it is not used by the plant in time, it will evaporate from the soil and be of no benefit to the crop. Some non-beneficial uses of water are weed transpiration, excess deep percolation, excess tailwater and canal/pipe seepage (Burt and Styles, 2011).

Application efficiency is typically used for a quick estimate of what the IE might be or evaluate one irrigation event. It is defined as the “average depth of irrigation water contributing to target” divided by the “average depth of irrigation water applied” (Burt, 2012). In equation form:

\[
AE = \frac{\text{Average Depth of Irrigation Water Contributing to Target}}{\text{Average Depth of Irrigation Water Applied}} \times 100
\]

Once again, there is another tricky term in the equation, “target.” The target could be the soil moisture depletion (SMD), the leaching requirement or just a target irrigation depth (Burt and Styles, 2011). This only works if there is assumed uniformity and does not take
into account beneficial uses discussed above. AE can also be used for evaluating a single irrigation event, whereas IE can be used for a variety of time intervals (Burt et al. 1999).

**Distribution Uniformity**

Distribution uniformity (DU) relates to the evenness of how the water is applied over the field. This means it is field dependent and cannot be displayed in terms of a farm, irrigation district, or basin. DU is defined as the “average low quarter depth of water” divided by the “average depth of water accumulated in all elements” (Burt and Styles, 2011). In equation form:

\[
DU = \frac{\text{Average Low Quarter Depth of Water}}{\text{Average Depth of Water Accumulated in All Elements}}
\]

Unlike efficiency, these values are expressed as decimals instead of percent’s. DU can be calculated for as little as one row of trees or vines to as much as the whole field. Due to the pressure differences, each tree/vine will see different amounts of water and thereby affect the DU. Differences in DU depend on the irrigation system present. See table below for potential DU values for various irrigation systems:

<table>
<thead>
<tr>
<th>Irrigation Method</th>
<th>Potential DU</th>
</tr>
</thead>
<tbody>
<tr>
<td>Permanent Under Tree Sprinkler</td>
<td>0.94</td>
</tr>
<tr>
<td>Orchard Drip</td>
<td>0.92</td>
</tr>
<tr>
<td>Row Crop Drip</td>
<td>0.90</td>
</tr>
<tr>
<td>Border Strip</td>
<td>0.85</td>
</tr>
<tr>
<td>Hand Move Sprinklers without alternate sets</td>
<td>0.75</td>
</tr>
</tbody>
</table>

Although the above table lists “potential DU” values, the actual values are almost always lower due to each irrigation design, the suitability of the design, and the management of the system (Burt, 1995).

Another term that affects DU in the drip/micro industry is the coefficient of variance (cv) which is the manufacturing variability of new emitters and sprayers (Burt and Styles, 2011). If there is a “cv” greater than 0.0, the plants will see some variability in the water that they will receive. Using this term DU can be rewritten mathematically:

\[
DU(cv) = \frac{1.27 \times \text{cv}}{\sqrt{n}}
\]

Where \( n \) = the number of emitters supplying each plant
Table 2: Classification of Brand New Emitter Manufacturer Quality (Burt and Styles, 2011)

<table>
<thead>
<tr>
<th>Classification</th>
<th>Manufacturing cv</th>
</tr>
</thead>
<tbody>
<tr>
<td>Excellent</td>
<td>&lt; 0.03</td>
</tr>
<tr>
<td>Average</td>
<td>0.03 – 0.07</td>
</tr>
<tr>
<td>Marginal</td>
<td>0.07– 0.10</td>
</tr>
<tr>
<td>Very Poor</td>
<td>&gt; 0.10</td>
</tr>
</tbody>
</table>

**Evapotranspiration**

Evapotranspiration (ET) is the sum of the plant transpiration and the evaporation of water from the wet soil or plant surfaces (Burt, 2012a); both of which are crucial for plant health and growth. ET does not take into account spray losses from the sprinkler or from moderate to high wind levels. This water that the plant uses in its ET is the requirement that each irrigation system needs to be able to provide on a monthly or yearly basis. Typically, the peak ET rate/month is found and the system is designed to be able to provide that amount of water.

Transpiration is the water that passes from the soil into the plant roots, through the plants, and out the leaves into the air (Burt, 2012a). This means that the majority of water movement from the roots to the leaves is mostly in the liquid form and finally water vapor once it leaves the stomata. As talked about before in the efficiency term, this transpired water is typically the main use of the “beneficially used” water (Burt, 2012a). The temperature and humidity of the soil and air also have an effect of transpiration. Hotter, drier air results in a higher transpiration rate (Burt, 2012a) which is why the peak ET month occurs during the hotter, drier summer months of June and July; vice versa for the temperature and humidity of the soil.

Evaporation is the water that is converted from liquid to gas in the plant atmosphere but does not pass through the plant like the transpiration water (Burt, 2012a). Some examples of this could be variations of soil evaporation, wet foliage evaporation or sprinkler spray losses. Soil evaporation represents the majority of the annual evaporation for a crop (Allen et al., 1998) and even though drip systems have less of an area wet, they still have the same amount of evaporation as sprinklers. This is because the drip systems keep a small portion of the soil wet for a long period whereas a sprinkler system gets a large area wet for a short time (Burt, 2012a). Wet foliage evaporation is highly dependent on the crop but not prevalent in a drip system for a vineyard. The foliage in a vineyard only gets wet during a frost protection event and evaporation doesn’t matter in that situation. Lastly spray loss from sprinklers is usually in a range of 1-4% for typical sprinkler systems (Burt, 2012a). Once again, spray losses will not affect the design of the drip system for the vineyard.
Table 3: Monthly grape vine ET values for Zone 8 in a typical California year (ITRC.org)

<table>
<thead>
<tr>
<th>Month</th>
<th>Precipitation</th>
<th>Reference ET</th>
<th>40% Canopy</th>
<th>60% Canopy</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>No Cover</td>
<td>Cover Crop</td>
</tr>
<tr>
<td>January</td>
<td>6.76</td>
<td>0.75</td>
<td>0.84</td>
<td>0.86</td>
</tr>
<tr>
<td>February</td>
<td>0.36</td>
<td>2.30</td>
<td>0.99</td>
<td>1.79</td>
</tr>
<tr>
<td>March</td>
<td>1.27</td>
<td>3.64</td>
<td>1.49</td>
<td>2.36</td>
</tr>
<tr>
<td>April</td>
<td>1.37</td>
<td>5.19</td>
<td>2.66</td>
<td>3.51</td>
</tr>
<tr>
<td>May</td>
<td>1.15</td>
<td>6.72</td>
<td>3.75</td>
<td>4.66</td>
</tr>
<tr>
<td>June</td>
<td>0.41</td>
<td>7.03</td>
<td>3.23</td>
<td>4.13</td>
</tr>
<tr>
<td>July</td>
<td>0.22</td>
<td>6.92</td>
<td>2.74</td>
<td>3.70</td>
</tr>
<tr>
<td>August</td>
<td>0.72</td>
<td>5.88</td>
<td>2.48</td>
<td>3.39</td>
</tr>
<tr>
<td>September</td>
<td>0.02</td>
<td>5.17</td>
<td>1.03</td>
<td>2.11</td>
</tr>
<tr>
<td>October</td>
<td>1.11</td>
<td>3.33</td>
<td>0.92</td>
<td>2.00</td>
</tr>
<tr>
<td>November</td>
<td>8.44</td>
<td>1.06</td>
<td>0.55</td>
<td>0.73</td>
</tr>
<tr>
<td>December</td>
<td>3.29</td>
<td>1.22</td>
<td>1.13</td>
<td>1.32</td>
</tr>
<tr>
<td>Total:</td>
<td>25.11</td>
<td>49.20</td>
<td>21.82</td>
<td>30.56</td>
</tr>
</tbody>
</table>

As seen in Table 3 above, these are the values for grape vines grown in CIMIS Zone 8 (Northern Ca) during a typical year of rainfall. These values were collected off of the ITRC.org website after selecting the proper CIMIS Zone. From this table one can see that the critical times for ET are in the earlier months of fruit production, May and June. Also, the more canopy cover the vines have the less ET it will experience on a yearly basis. When looking at this data, the irrigation design will be designed to supply enough water to satisfy the peak ET/month rate.

**Soils**

In order to get soils information for the particular area of the design, the Natural Resources Conservation Service (NRCS) website was used. On the website NRCS has Web Soil Survey (WSS) and if one knows the location of any field in the country, a free soils report will be provided for that area. For example, the field was outlined on the website, then a report was generated by the shape of the field, the location of the field and the soils involved with that field. Below in Figure 2 and Figure 3 are some of the results from the report.
From this report, an estimate of the size of the field is given before being surveyed, the soil types and the percent slopes are all given. From these tables, the field in question has relatively low percent slopes, and very loamy soils; in this location Russian loam or Cole clay loam dominate. It is important to get soil data because the soil characteristics determine a lot of the irrigation design restraints. For example, the Russian loam with gravelly substratum has a available water holding capacity (AWHC) of approximately 6.6 inches per foot whereas the Russian loam can hold approximately 9.6 inches. Characteristics like these affect the amount of water available to the plant in the soil, the infiltration rate and how often to irrigate.

**Pipeline Hydraulics**

Water moves from a point of higher energy to a point of lower energy and friction happens between those two points (Burt, 2011). This is important to recognize because there is also a decrease in energy that goes along with water moving from one point to another whether it is flowing by gravity or being pumped. In order to account for
pressures, elevations, and velocities of water in a pipe Bernoulli’s equation is used. From the BRAE 312 textbook, Basic Hydraulics, the Bernoulli equation goes as follows:

\[
\left[\left(\frac{V^2}{64.4}\right) + \text{Elev} + P\right]_{\text{u/s}} = \left[\left(\frac{V^2}{64.4}\right) + \text{Elev} + P\right]_{\text{d/s}} + \text{Hf} - \text{Hp}
\]

Where,
- \(V\) = the velocity of the water
- \(\text{Elev}\) = the elevation of the point in question
- \(P\) = the pressure at the point in question
- \(\text{Hf}\) = the friction loss that occurs from the u/s point to the d/s point
- \(\text{Hp}\) = the added energy from a pump

The left side of the equation refers to the upstream point (u/s) and the right side refers to the downstream point (d/s).

Other equations used to calculate the friction loss between two points in a pipe are the Darcy-Weisbach and Hazen-Williams.

Darcy Weisbach is the most correct form of a hose friction loss equation and is used in most computer programs (Burt and Styles, 2011). The equation is seen below:

\[\text{Hf} = f \frac{LV^2}{2Dg}\]

Where,
- \(\text{Hf}\) = friction loss
- \(V\) = velocity of water
- \(L\) = pipe length in question
- \(D\) = inside diameter of pipe
- \(g\) = gravitational constant
- \(f\) = friction factor depending on Reynolds number (Re)
- \(\mu\) = kinematic viscosity of water

The Reynolds number is a dimensionless number defined below (Burt and Styles, 2011):

\[\text{Re} = \frac{VD}{\mu}\]

The Moody Diagram is frequently used to find the correct friction factor if given the Reynolds number and the relative roughness of the pipe in question (Burt and Styles, 2011).

Hazen-Williams is the friction computation equation used by most irrigation designers due to the complexity of the Moody Diagram and the Darcy-Weisbach equation. This is
an empirical equation used with a variety of materials such as PVC, aluminum, etc. (Burt, 2011). The equation goes as follows:

\[
Hf = K \times L \times \frac{GPM^{1.852}}{C} \times ID^{-4.87}
\]

Where,
- \(K\) = a constant of 10.5 for English units
- \(Q\) = flow rate of pipe
- \(ID\) = inside diameter of pipe
- \(C\) = friction factor depending on the type of pipe material and size

Pipe “C” values can be found in the BRAE 312 Basic Hydraulics textbook on page 1-25 in Table 1-7. For example, the “C” value of PVC pipe is 150 whereas the “C” value of old cast iron is 100. Now looking at the equation above, the lower “C” value results in higher friction losses over that segment of pipe.

**Frost Protection**

Frost protection is the act of protecting a crop from freezing and irrigation has been proven to be very effective/widely used in California with orchards and vineyards (Burt, 2012a). There are five major terms that drastically affect freezing and frost protection. Below are the definitions of the terms according to the BRAE 331 Ag-Irrigation Management Textbook (Burt, 2012a):
1. Dew-Point Temperature: The temperature at which vapor in the air will condense. Dew will form on a cold surface, at or below the dew point temperature, as moisture laden air passes over that surface.
2. Relative Humidity: The ratio of the actual vapor pressure in the air to the saturation vapor pressure, times one hundred. At a relative humidity of 100%, the air can hold no more water vapor at that temperature.
3. Wet Bulb Temperature: The temperature recorded by a thermometer that is swung around through the air, with a wet wick over the bulb. This is also the temperature to which the air will drop when the sprinklers are turned on. If the air has a low relative humidity, the wet bulb temperature is much lower than the dry bulb temperature.
5. Inversion Layer: A later of cold air is near the ground surface, while air several tens or hundreds of feet higher is warmer.

There are two types of freezes that affect vineyards in California: advective freezes and radiation freezes (Minton et al, 2011). Advective freezes deal with the wind taking the heat away from the orchard or vineyard, then blowing cold air in (Burt, 2012a). It is very hard if not impossible to protect against advective freezes with sprinklers. Radiation freezes on the other hand occurs when the heat from the ground radiates upward in the form of long wave radiation (Minton et al, 2011). Radiant freezes are often accompanied by an inversion layer (Burt, 2012a). When the temperature drops below the dew point...
temperature, frost will appear. Sprinklers and other irrigation have been proven to be very effective against radiant freezes.

Vines are more or less susceptible to freezes depending on the time of year. For example, in the heart of winter, the vines are dormant and the freezing temperatures have no effect on the vines. However during bud break and blossom in the spring, the vines are very sensitive to freezes (Burt, 2012a). In order to protect from freezes, farmers can store heat in the soil in the form of water during the day, they can keep grass levels well maintained in the vineyard and they can avoid border barriers that will make cold air pool and intensify the freezing situation (Minton et al, 2011). If the above techniques aren’t enough, one can use active techniques such as wind machines or irrigation to protect against frost. Ironically, when water freezes heat is released. This is the most effective type of frost protection (Burt, 2012a) and can be used to protect the vines up to 10-15°F below freezing.

As far as general recommendations for frost protection the BRAE 331 textbook offers some basic guidelines (Burt, 2012a):

- Size the reservoir supplying the water for frost protection for three to four nights in a row of ten hours of operation. Therefore, make sure the reservoir should be large enough to handle 30-40 hours of continuous irrigation from the overhead sprinklers.
- The overhead sprinklers in the vineyard must have a good catch can distribution uniformity (CCDU) because frost protection relies on direct water contact with the plant.
- Wind speed, humidity and temperature affect the application rate of water needed. Lower temperatures require more water along with higher wind speeds.
- See Table 4 below for freeze protection system starting temperatures. Note: After sunrise with no wind, sprinklers can be turned off at 32°F and if wind 34°F.

Table 4: Air temperatures at which irrigation system should be started for proper protection.

<table>
<thead>
<tr>
<th>Dew Point Temperature, deg F</th>
<th>System Starting Temperature, deg F</th>
</tr>
</thead>
<tbody>
<tr>
<td>26+</td>
<td>34</td>
</tr>
<tr>
<td>24-25</td>
<td>35</td>
</tr>
<tr>
<td>22-23</td>
<td>36</td>
</tr>
<tr>
<td>20-21</td>
<td>37</td>
</tr>
<tr>
<td>17-19</td>
<td>38</td>
</tr>
<tr>
<td>15-16</td>
<td>39</td>
</tr>
</tbody>
</table>

**Spacing**

When designing the vineyard two different spacing terms will have an effect: row spacing and vine spacing. According to Kurtural (2007), one common fallacy with designing vineyards is to design to the current equipment owned by the farmer. This should not be the case because proper row spacing is needed for optimal production. Instead, equipment should be procured to fit the designed spacing. Vine spacing can predict how many vines there will be per acre but once again, the designer can’t use any
arbitrary value. The vine spacing needs to match the vine type and the desired fruit quality. The highest yields have typically come from vineyards containing 600 or more vines per acre however ideal spacings are found to be about 600 vines per acre (Kurtural, 2007). According to the table below this translates to a spacing of 8’ by 9’.

Table 5: Vines per acre needed based on spacing.

<table>
<thead>
<tr>
<th>Vine Spacing (ft)</th>
<th>7.5</th>
<th>8</th>
<th>8.5</th>
<th>9</th>
<th>9.5</th>
<th>10</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>1162</td>
<td>1089</td>
<td>1025</td>
<td>968</td>
<td>917</td>
<td>871</td>
</tr>
<tr>
<td>6</td>
<td>968</td>
<td>908</td>
<td>854</td>
<td>807</td>
<td>764</td>
<td>726</td>
</tr>
<tr>
<td>7</td>
<td>830</td>
<td>778</td>
<td>732</td>
<td>691</td>
<td>655</td>
<td>622</td>
</tr>
<tr>
<td>8</td>
<td>726</td>
<td>681</td>
<td>641</td>
<td>605</td>
<td>873</td>
<td>545</td>
</tr>
</tbody>
</table>
PROCEDURES AND METHODS

Irrigation Design Procedures

This section will go over the design and calculations of the irrigation system.

Preliminary Data Supplied by Grower

Before every irrigation system can be designed a lot of given information needs to be supplied by the grower or collected by the designer. More information that is given to the designer will result in a better final product. Major factors that need to be considered include: field location, field size, field shape, crop, row orientation, ET values, water source, field slope, soil type, crop spacing, and hours of operation. These are just the bare minimum needed to design a proper irrigation system; more information, like stated above, will result in a better design. If any of these are not supplied by the grower, they need to be pursued by the designer.

For this design the givens supplied by the grower are:
Location: Potter Valley, Ca
Water Source: Reservoir
Crop: Wine Grapes
Field Size: 25.27 acres
Row Orientation: East to West
Vine Spacing: 8’ by 6’
Soil Type: Russian Loam
Peak ET, c: 4.95 in/month
Peak ET, c Month: May
Slope West to East: 0.02%
Slope North to South: 0.03%

Along with the given information come the constraints or restrictions that are placed on the field due to the area or the grower. Some restrictions include: existing pipelines and equipment, salinity problems, infiltration problems, specific equipment desired, water supply and hours of operation.

For this design some of the constraints are:
Max Hours of Operation: 18 hours/day
Drip Hose: Netafim Uniram
System DU: 0.92
Existing Pipeline: 10” PVC coming from pumping station

**Field Layout**

Once the above factors are figured out the designer can take a look at the size and shape of the field in question. Luckily this design for Dan Todd’s field turned out to be a very nice shape; the little section in the northwest corner of the field is the only thing making it not square. The surveying of the field was done by a local surveyor and the data was relayed through the grower. Seen below in Figure 5 is the field outline.

![Field layout and dimensions supplied by grower.](image)
Also in Figure 5, one can see the existing 10” pipe that Dan wants to incorporate into the mainline of the irrigation design.

**Peak ET Calculation**

In order to properly supply the crop with enough water the peak ET rate needs to be found. Peak ET values can be found on itrc.org website and are then categorized by the crop being evaluated, the zone it will be grown in and the yearly rainfall characteristic (dry, typical or wet). For this design with wine grapes in Zone 8, the peak ET value for a typical year was 4.95 inches/month in the month of May. This translates to 0.16 inches/day which is more helpful than the monthly value.

**Gross Application Rate Determination**

The net required flow rate per vine is the amount of water needed by the plants per day. This is based off of the vine spacing, the peak ET rate and the hours of available operation. This equation looks like:

\[
\text{GPM}_{\text{net/Vine}} = \frac{\text{inches/day} \times \text{vine spacing}}{96.3 \times \text{hours of operation}}
\]

For this design, the givens are:
Inches/day: 0.18
Vine Spacing: 8’ by 6’
Hours of Operation: 18 hrs/day
Design DU: 0.92
Future DU: 0.86

This results in a net flow rate of 0.0049 GPM/vine or 0.292 GPH/vine. This however doesn’t give us the total amount needed. In order to get that, the DU of the system has to be taken into account. The equation for the gross GPH/vine is:

\[
\text{GPH}_{\text{gross/Vine}} = \frac{\text{GPH}_{\text{net/Vine}}}{\text{Future DU}}
\]

The reason the DU is taken into account is because not every vine will be getting the same amount of water. Dividing by the DU will make sure all the vines get at least all the water they need if not more. In this design the future DU will be used instead of the design DU because even though the system will operate at the design DU for a while, after a few years the DU will go down. This way, the design is ready for the worst case scenario. This results in a gross flow rate of 0.340 GPH/vine.

**Emitters per Vine Estimation**

For a good irrigation system, the designer should make sure there is at least 60% wetted area. For this design, there should be at least 48 ft² of wetted area. According to Burt and Styles (2007) water will also travel laterally through the soil meaning water will travel
beyond where the dripper drops. This additional lateral movement due to a loamy soil will add 3.75’ to the wetted diameter calculation. Drip already has a wetted diameter of 2’ so this will result in a total diameter of 7.5’. In order to get the percent wetted area, one just has to divide the wetted area by the vine spacing. For this design, the wetted area percentage comes out to be 92%, which means one dripper per vine would be adequate. Although one dripper per vine would work, the drip hose desired by the farmer, Netafim Uniram, doesn’t come with 72” emitter spacings. This means 36” emitter spacing will need to be used and two emitters per vine.

**Hours of Operation Correction**

The calculations done above about the gross flow rate needed per vine assumed one emitter per vine but since there are two emitters per vine, the hours of operation need to be corrected. The drip hose has 0.260 GPH/emitters which will result in 0.520 GPH/vine. This 0.520 GPH/vine is greater than the 0.340 GPH/vine required, so our hours of operation will be decreased. An equation from above will be manipulated to give hours of operation required.

\[
\text{GPM}_{\text{gross/Vine}} = \frac{\text{(in/day} \times \text{vine spacing} \times \text{DU} \times \text{emitters/vine})}{(96.3 \times \text{hours of operation})}
\]

The reduced hours of operation required are 11.76 hours/day or 82.29 hours/week. This means Dan can irrigate however long he wants per day as long as the weekly total is greater than 82.29 hours.

**Hose Lateral Inlet Pressure Calculations**

Netafim Uniram drip hose is a pressure compensating (PC) drip hose. This means that as long as the pressure at each emitter is greater than the threshold pressure, each emitter will distribute the same amount of water. The threshold pressure for Netafim Uniram is 7 psi. This means the absolute minimum pressure at the end of each lateral must be at least 7 psi. As water is flowing through a lateral, energy is being lost and therefore going down in pressure. This means, as the laterals get longer and depending on the size of the hose, the required inlet pressures are different. The Irrigation Training and Research Center (ITRC) has a DOSBox program called PLACEM4.exe that will do this for the designer. The inputs to the program are: desired flow rates, nominal flow rates, emitters per vine, emitter spacing, additional length for expansion/contraction, total length of lateral, manufacturing coefficient of variance (CV), water temperature, slope and the emitter discharge exponent.

For this design, the inputs are:
- GPH/Emitter: 0.260 GPH
- Avg Emitter Pressure: 13 psi
- Nominal Flow Rate: 0.260 GPH
- Emitters/Vine: 2
- Emitter Spacing: 36”
- Additional % for Snaking: 2.5%
Manufacturing CV: 0.025
Total Length of Field: 1140’
Water Temperature: 70°F
Slope: 0.02%
Discharge Exponent: 0.0001

These givens were determined by steps done earlier in the design. The 13 psi was chosen because it is high enough above the 7 psi threshold pressure. As a designer, the lowest pressure in the line should be nowhere near the threshold pressure. Also, the manufacturing data claims a discharge exponent of zero (because of the pressure compensating emitters), but the program can’t handle that; an exponent of 0.0001 was used to circumvent that. All the possible hose sizes were used but each resulted in the same DU. Therefore, the smallest hose diameter (0.540) was chosen because it is cheaper and easier to deal with. This program also tells where to put the manifold due to the constraints entered. PLACEM4 said to put the mainline 559’ uphill and 581” downhill. The inlet pressure required was 14.6 psi and the DU was 0.97.

<table>
<thead>
<tr>
<th>Hose ID (in)</th>
<th>Manifold Placement</th>
<th>DUₙ</th>
<th>Max Δ PSI</th>
<th>Inlet GPM</th>
<th>Inlet PSI</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Lengthₘₙₐₙ (ft)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.540</td>
<td>559</td>
<td>581</td>
<td>0.97</td>
<td>2.0</td>
<td>1.65</td>
</tr>
<tr>
<td>0.570</td>
<td>559</td>
<td>581</td>
<td>0.97</td>
<td>1.5</td>
<td>1.65</td>
</tr>
<tr>
<td>0.620</td>
<td>559</td>
<td>581</td>
<td>0.97</td>
<td>1.0</td>
<td>1.65</td>
</tr>
<tr>
<td>0.690</td>
<td>559</td>
<td>581</td>
<td>0.97</td>
<td>0.6</td>
<td>1.65</td>
</tr>
</tbody>
</table>

Although this program is very accurate it is good to check what PLACEM4 outputs with data supplied from Netafim. Netafim supplies pressure loss graphs depending on the length of the laterals. Using the longest length of the lateral (581’) and the 0.260 GPH emitter, the pressure loss was ~2.5 psi. This means the required inlet pressure to the manifold would have to be 15.5 psi which is greater than what PLACEM4 said. In order to make sure the system will work in the worst case scenario, an inlet pressure of 15.5 psi will be used on the last hose lateral.

**Sizing of the Manifold**

The next step in the design process is to properly size the manifold that serves each of the laterals. With a total field length of 1020’, the total number of rows comes out to 128.5. Since that is not possible, the north end of the field will have extra space along the border. Dan already has an existing 10” pipe in the ground from the irrigation system for his previous crop, organic pears. By keeping this pipe in, a lot of money will be saved when he decides to put the system in. The location of this 10” pipe is 340’ south of the north border of the field. When sizing the manifold the designer has to take into account the slope of the field along the manifold, the different sizes of pipe, the different flow rates, the pressure loss due to friction and the total overall energy loss from lateral to
lateral. In this particular design the pressure regulating point, the pressure compensating emitters, is downstream of the manifold. This creates a situation where the manifold is sized due to economics instead of DU. A maximum water velocity of 4.5 feet per second was used and when that value was hit, a change in pipe size occurred. The manifold to the south was analyzed first and resulted in an inlet pressure of 19.55 psi and a flow rate of 141.9 GPM, where the manifold meets the mainline. The manifold north of the mainline resulted in an inlet pressure of 17.52 psi and a flow rate of 69.3 GPM. This means that at least 19.55 psi is required where the manifold and the mainline meet.

**Flushing Requirements**

Another DOSBox program developed by the ITRC is SINGLE4.exe. This program can do three different tasks but in this design it was used to find the flushing requirements. The inputs for this program are hose diameter, emitter spacing, total lateral length and flushing velocity. A flushing velocity of 1.5 ft per second was used resulting in a flushing flow rate of 1.91 GPM per lateral. Since this is greater than the flow rate used for irrigation, only a fraction of the laterals can be flushed at one time. Of the total laterals, only 110 can be flushed at the same time with the flow rate coming from the pump.

**Mainline Sizing**

The mainline is the segment of pipe that connects the manifold to the pump and is represented by the segment from “A” to “C” in Figure 6. Usually in an irrigation design, the mainline will involve the proper pipe sizes to save money but in this design there is an existing 10” pipe that will be used.

![Figure 6: Schematic of how the mainline is oriented in the field.](image)

Although the pipe already exists and the size has already been determined, the calculations are done in order to find the total dynamic head (TDH) required by the pump. This takes into account the energy loss due to friction and the energy loss or gain due to changes in elevation. These calculations resulted in a 19.57 psi requirement downstream of the filter station.
Field Flow Rate = 211.20 GPM
Slope Down Rows (West to East) = 0.02%
Slope Between Rows (North to South) = 0.03%

Table 7: Mainline sizing table.

<table>
<thead>
<tr>
<th>Point</th>
<th>Point P (PSI)</th>
<th>U/S Segment Q (GPM)</th>
<th>ID (in)</th>
<th>Segment Length (ft)</th>
<th>Segment Hf (PSI)</th>
<th>Δ Elev (PSI)</th>
<th>Δ P (PSI)</th>
<th>Velocity (ft/sec)</th>
</tr>
</thead>
<tbody>
<tr>
<td>C</td>
<td>19.55</td>
<td>211</td>
<td>10.226</td>
<td>581</td>
<td>0.061</td>
<td>-0.0503</td>
<td>0.0106</td>
<td>0.83</td>
</tr>
<tr>
<td>B</td>
<td>19.56</td>
<td>211</td>
<td>10.226</td>
<td>30</td>
<td>0.003</td>
<td>0.0039</td>
<td>0.0070</td>
<td>0.83</td>
</tr>
<tr>
<td>A</td>
<td><strong>19.57</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Filtration Requirements**

All or most water needs to be filtered before it can enter an irrigation system. Some exceptions to that is surface irrigation because it doesn’t have to pass through any small orifices. Other irrigation practices such as drip, microspray, sprinkler, etc. need to be filtered otherwise the system could experience plugging or other problems. Although the irrigation types mentioned need filtration, the degree of filtration varies with each type. Sprinkler irrigation has much larger orifices than drip, therefore requiring much less filtration. A basic concept of filtration is to remove particles in the water that are larger than 1/7th of the orifice diameter. In this drip design, Netafim makes it easy because they recommend 120 mesh and that is what will be used. In the sand media filters, #8 crushed granite will be utilized in four 30” sand media tanks. These components were chosen using the filtration mesh size, the total flow rate and the dirt load in the water.

Table 8: Opening and mesh size used in sand media tanks.

<table>
<thead>
<tr>
<th>Mesh Size</th>
<th>Opening Size (in)</th>
<th>mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>20</td>
<td>0.028</td>
<td>0.711</td>
</tr>
<tr>
<td>80</td>
<td>0.0071</td>
<td>0.180</td>
</tr>
<tr>
<td>100</td>
<td>0.006</td>
<td>0.152</td>
</tr>
<tr>
<td><strong>120</strong></td>
<td><strong>0.0049</strong></td>
<td><strong>0.124</strong></td>
</tr>
<tr>
<td>150</td>
<td>0.0041</td>
<td>0.104</td>
</tr>
<tr>
<td>200</td>
<td>0.003</td>
<td>0.076</td>
</tr>
</tbody>
</table>
Table 9: Media selection table for filters.

<table>
<thead>
<tr>
<th>Media #</th>
<th>Media Type</th>
<th>Mean Effective Media Size</th>
<th>Mean Filtration Capacity (mm) (@15-25 GPM/ft^2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>12</td>
<td>Round Monterey Sand</td>
<td>1.30</td>
<td>0.16 - 0.15</td>
</tr>
<tr>
<td>16</td>
<td>Round Monterey Sand</td>
<td>0.65</td>
<td>0.12 - 0.15</td>
</tr>
<tr>
<td>8</td>
<td>Crushed Granite</td>
<td>1.50</td>
<td>0.11 - 0.15</td>
</tr>
<tr>
<td>12</td>
<td>Crushed Silica</td>
<td>1.20</td>
<td>0.11</td>
</tr>
<tr>
<td>20</td>
<td>Round Monterey Sand</td>
<td>0.50</td>
<td>0.11</td>
</tr>
<tr>
<td>11</td>
<td>Crushed Granite</td>
<td>0.78</td>
<td>0.08 - 0.11</td>
</tr>
<tr>
<td>16</td>
<td>Crushed Silica</td>
<td>0.70</td>
<td>0.08 - 0.10</td>
</tr>
<tr>
<td>20</td>
<td>Crushed Silica</td>
<td>0.47</td>
<td>0.06 - 0.08</td>
</tr>
</tbody>
</table>

Table 10: Filtration specifications

<table>
<thead>
<tr>
<th>Flowrate (GPM)</th>
<th>Number and Size of Media Tanks</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Moderate Dirt Load</td>
</tr>
<tr>
<td>50</td>
<td>35</td>
</tr>
<tr>
<td>100</td>
<td>70</td>
</tr>
<tr>
<td>150</td>
<td>105</td>
</tr>
<tr>
<td>275</td>
<td>192</td>
</tr>
<tr>
<td>425</td>
<td>299</td>
</tr>
<tr>
<td>575</td>
<td>399</td>
</tr>
<tr>
<td>775</td>
<td>539</td>
</tr>
<tr>
<td>1025</td>
<td>719</td>
</tr>
<tr>
<td>1275</td>
<td>899</td>
</tr>
</tbody>
</table>

The water used to backflush the sand media tanks will be put back into the reservoir in order to be used later. It is important to put this outlet a distance away from the pump inlet so that the dirty water that was just taken out of the filters doesn’t immediately go back into the filters. See the filter station detail in Appendix E for layout and details.

**Total Dynamic Head**

The total dynamic head (TDH) is the amount of energy the pump or series of pumps needs to put into the water to properly supply the irrigation system. As discussed earlier in the report, a threshold pressure needs to be maintained otherwise the Netafim Uniram emitters won’t work properly. This would then result in the vines not getting the required water they need for survival. From the design of the mainline, the pressure needed at the discharge of the pump was 19.57 psi. Other losses that will occur in the system will come from dirty sand media filters, preliminary screen filters, minor losses and the height from
the manifold to the vine. This TDH totals up to 32.89 psi or 75.97 ft of pressure. Using this TDH value and the flow rate the pump can be properly chosen and supplied to Todd Farms.

<table>
<thead>
<tr>
<th>Table 11: Total dynamic head (TDH) calculations.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pressure Required Downstream of Filters =</td>
</tr>
<tr>
<td>Dirty Media Filter Loss =</td>
</tr>
<tr>
<td>Emergency Screen Loss =</td>
</tr>
<tr>
<td>Manifold to Vine Height =</td>
</tr>
<tr>
<td>Manifold to Vine Height =</td>
</tr>
<tr>
<td>Minor Losses =</td>
</tr>
<tr>
<td>Required Pump TDH =</td>
</tr>
<tr>
<td>Required Pump TDH =</td>
</tr>
</tbody>
</table>

**Air/Vacuum Release Vents**

Air vents are a very important part of every drip design and are used to let air in or out of the system at startup, while the system is running, and when the system turns off. According to Burt and Styles (2012b) an air vent should be placed every quarter of a mile, at all high points and downstream of every air entrance to the system. Just as important as air vents is vacuum relief valves. They should also be placed at all high points and downstream of shutoff valves. Since this design is relatively small with short pipe runs air vents will be placed at the end of each manifold (North and South) and downstream of the pump. Vacuum relief valves will be placed at the high point along with the air vent but also downstream of the shutoff valve so water can recede back into the reservoir. See the drawing in Appendix E for more detail on where the air vents will be placed.

**Reservoir Enlargement Design Procedures**

This section will go over the design and calculations of the reservoir enlargement.

**Preliminary Data Supplied From Grower**

Once again, in order to make sure the reservoir has enough storage for both irrigation needs and frost protection needs, proper data needs to be relayed to the designer. In this case a lot of those givens are the same bits of data. For this part of the design some of the givens include: field size, vine spacing, sprinkler spacing, catch can DU (CCDU), flow rate DU (GPMDU), wind speed, days of frost and hours of operation.

For this design those givens are:
Field Size: 25.27 acres
Vine Spacing: 8’ by 6’
Sprinkler Spacing: 48’ by 36’
GPMDU: 0.82
Low Temperature: 22 °F
Wind Speed: 1 mph
Consecutive Days of Frost: 4 days
Hours of Operation: 11 hours/night
Sprinkler Type: Nelson R33 Rotator

![Figure 7: Current reservoir with pumping station on left.](image)

Although this design will not incorporate the actual design of the over-vine frost protection sprinkler system, these givens had to be found in order to calculate the total amount of storage needed.

**GPM/Sprinkler Calculations**

According to the BRAE 331 textbook, a low temperature and a 1 mph wind speed results in a net application rate of 0.18 inches per hour. This value divided by the GPMDU turns out to be 0.22 inches per hour. Once again the GPM per sprinkler equation is used and the required flow rate is 3.95 GPM per sprinkler.

**Sprinkler Selection**

Once the flow rate per sprinkler is determined, the designer needs to select a sprinkler that can efficiently supply that amount of water. In the case of this design, Dan wants to use Nelson R33 Rotator sprinklers. He had talked to a few other local growers and those with these plastic sprinklers from Nelson had experienced no vandalism. Some of the
growers with the traditional metal sprinklers had a few areas cleaned out and probably sold for scrap metal. The Nelson R33 Rotators are also very easy to disassemble and put back together if one of their parts fails. Due to the required 0.22 inches per hour application rate determined in the previous steps, the Gold 18 sprinkler with a nozzle size of 9/64” was chosen. When used with the average K-Value the operating pressure turns out to be 47.14 psi. Since the actual over the vine frost protection system will not be designed in this project, this value is somewhat irrelevant for the design. Although the operating pressure is not used, it is interesting to see the much higher pressures that the sprinkler systems work at compared to drip irrigation.

**GPM/Acre Determination**

This was a fairly easy calculation to go through with. Since the flow rate per sprinkler was defined above the only thing left was to find the number of sprinklers per acre and multiply them together. It turns out that there are approximately 25.2 sprinklers per acre resulting in 99.6 GPM per acre.

**Total Storage Required**

The total storage needed in the reservoir is the sum of the storage needed for four consecutive days of frost protection plus an additional 10% for insurance. Water storage needed for irrigation is not taken into account because during the frost protection months, the vines are not using very much water. Also, some of the water applied during the frost protection events is beneficially used to satisfy the plants small ET needs.

For each frost protection event the system will run 11 hours per night totaling 44 hours. This time when multiplied by the number of acres and the flow rate per acre for the frost protection will yield the amount of storage needed just for frost protection. Then to make sure everything works, add an additional 10% to the total amount of storage for insurance. This sum comes out to be 22.4 acre feet of water. This means, Dan needs to increase his current reservoir until it is at least 22.4 acre feet.

<table>
<thead>
<tr>
<th>Table 12: Reservoir sizing calculations.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Storage Needed =</td>
</tr>
<tr>
<td>Insurance Storage (10%) =</td>
</tr>
<tr>
<td><strong>Total Storage Needed =</strong></td>
</tr>
</tbody>
</table>
RESULTS

The 25.3 acre drip irrigation design and reservoir enlargement for Todd Farms was completed. The field will be irrigated on one set with a very high distribution uniformity using Netafim Uniram drip tape. The design will incorporate existing pipe for the mainline and new pipe for the manifold that supplies the drip hose laterals. There will be two emitters per vine on 36” emitter spacing. The drip hose has an inside diameter of 0.540” and a flow rate of 0.260 GPH. The irrigation system is supplied by water in the reservoir in the northeast corner of the field and will require a booster pump. The TDH required by the pump is 75.97’ and the total flow rate for the field is 211 GPM.

Once the irrigation design was completed the reservoir enlargement calculations were done. This resulted in a total storage need of 22.4 acre-feet of water for both frost protection and irrigation needs. After a recent conversation with Dan Todd they started the excavation for the reservoir enlargement and can be seen in the figure below.
Figure 9: The beginning of the reservoir enlargement.
DISCUSSION

The most difficult part of the design was to design the manifold that supplied the drip hose laterals. This was due to the variation in pipe sizing that occurred along the manifold and the small changes in elevation. The reason the pipe sizes changed along the manifold was because as the manifold got longer, less flow was traveling through the pipe. A designer could simply use one large pipe size for the whole manifold but that would affect the DU of the system and cost the grower a lot more money to install. This also took some finesse by the designer to know when to change to a smaller or larger diameter pipe; thankfully the experience from BRAE 414 really helped out.

Although the reservoir enlargement was accurately estimated, the values used to come up with the total storage needed should not be final. The actual designer that completes the over vine sprinkler system should also do an analysis on how much water is needed for the actual design that will be protecting the crop. This frost protection design will also use some of the same segments of pipe which will increase the size of pipe required.

This design, like all other irrigation systems, was designed specifically for the plot of land in Potter Valley, Ca. Unfortunately, this is the only place that can utilize it and still allow it to work properly. Also, every component of the design acts as one smaller part of the larger picture. This means that if only bits and pieces of the design are utilized, the performance would greatly decrease.

In the past Dan Todd has only surface irrigated his pear orchards which cost barely anything at all to run. All surface irrigation is gravity fed using dirt or concrete lined ditches to bring the water to the head of the field. Dan doesn’t have a tailwater recovery system which can collect and recirculate water more efficiently. This drip design for his vines is a permanent irrigation system and could lead to more up to date systems in the future. This could eliminate some of the labor involved with surface irrigation along with some of the other costs. Although the existing surface irrigation practices are working for Dan, the benefits of switching to drip or microspray would be worth it, especially considering the age of his systems.
RECOMMENDATIONS

If any changes were to happen to this design it would probably be focused on the hours of operation. The only constraint on that matter was to not operate on peak usage hours which are from noon to six, Monday through Friday. If Dan didn’t want to irrigate every day for 12 hours then he could run the system for any combination of hours per day as long as the minimum hours per week were met. If he drastically wanted to change the hours of operation to something was less, a new drip hose could be used. The new drip hose could have a larger inside diameter allowing more flow and would need emitters with a higher flow rate. This may be something Dan would want to look into because having to irrigate 84 hours per week is a huge time commitment.

Another issue that could come up would be with the filtration system. After talking to Steve Shepard, the local irrigation designer, he highly recommends using disc or screen filters instead of sand media tanks. This is because disc filters are cheaper and have a much smaller footprint on the land. An easier to maintain filter is more advantageous to the grower because it eliminates the possibility of negligence. Negligence of sand media tanks can cause a decline in performance of the whole system which would cost the grower more money and make the system run less efficiently.

Also due to recent flow measurement laws, Dan would need to install and use a flow meter for his vineyard. This however was not covered in the design but would be easy for him to do on his own; depending on how much Todd Farms wanted to pay there is a variety of options available. Some of those options are magnetic meters, propeller meters, etc. with the best option being to put in a McCrometer Mag Meter. The McCrometer Mag Meter also happens to be the most expensive option. This flow meter would be placed after the pump discharge but before the filtration station.

As for the reservoir enlargement, the 22.4 acre feet presented in the calculations and analysis earlier in the report is only a minimum value. Just to be safe it is recommended to increase the reservoir storage capacity to 25 acre feet or more. This may cost more initially but a farmer has never complained about having too much water at their disposal. Also, if silt or other solids collect in the bottom of the reservoir, storage capacity will slowly be decreased.
REFERENCES


APPENDIX A

HOW PROJECT MEETS REQUIREMENTS FOR THE BRAE MAJOR
**Major Design Experience**

The senior project is required to include major design experience garnered from classes while at Cal Poly. Design is the process of creating a system or component used to meet a set of given requirements.

**Establishment of Objectives and Criteria**

The objective of this project is to supply the grower with an efficient drip irrigation system that will work with minimal maintenance. Also, the storage needs for frost protection will be analyzed and a reservoir enlargement will be recommended.

**Synthesis and Analysis**

The project included an analysis of the following: soils represented in the field, hydraulic calculations and total volume required for four days of frost protection. This caused different trials or variations until the final and correct design was found.

**Construction, Testing and Evaluation**

The project will have no construction or testing involved. However, the irrigation system will be evaluated using calculations only.

**Incorporation of Applicable Engineering Standards**

The project will utilize and abide by Potter Valley Irrigation District, ASABE and ITRC standards.

**Capstone Project Experience**

The project will incorporate many concepts introduced in previous engineering classes including: BRAE 133 Engineering Graphics, BRAE 151 AutoCAD, BRAE 236 Principles of Irrigation, BRAE 312 Hydraulics, BRAE 331 Irrigation Theory, BRAE 414 Irrigation Engineering, SS 121 Introductory Soil Science and ENGL 149 Technical Writing.

**Design Parameters and Constraints**

The project will address a significant number of categories and constraints listed below.

**Physical**

The irrigation design must be sufficient for the vineyard in Potter Valley, Ca and the reservoir needs to be large enough to handle crop needs and frost protection.
**Economic**

N/A

**Environmental**

The irrigation design will minimize potentially harmful runoff and conserve as much water as possible through efficiency.

**Ergonomics**

N/A

**Manufacturability**

This design is specifically for Todd Farms in Potter Valley, Ca.

**Health and Safety**

Proper filtration will be utilized to distribute clean water to the crop and proper safety equipment will be used to protect the workers.

**Ethical**

N/A

**Political**

N/A

**Productivity**

The irrigation design will need to be productive and take care of the crops needs. The reservoir needs to be large enough to ensure proper frost protection.
APPENDIX B

Irrigation Design Calculations
Given:

- Crop = Wine Grapes
- Location = Potter Valley, CA
- Drop Hose = Netafim Uniram
- Field Size: 110,000 sq ft
- Field Size: 25.27 acres
- Field Length (N/S) = 100 ft
- Field Length (E/W) = 1140 ft
- Row Orientation = East to West
- Spacing:
  - Spacing Between Rows = 8 ft
  - Spacing Between Vines in a Row = 6 ft

- Soil Type = Russian Loam
- Root Zone Depth = 6 ft
- Peak ET, Month = May
- Peak ET, Day = 0.16 in/day
- Slope Between Rows (North to South) = 0.02%
- Slope Between Rows (North to South) = 0.03%
- Desired System DU = 0.92
- Max Hours of Operation = 18 hrs/day
- 7 days/week

Design:

1. Determine peak ET rate:
   - Peak ET Rate = 4.95 in/month
   - Peak ET Rate = 0.16 in/day
   - Assume 10% increase with drip irrigation

   Therefore, Peak ET Rate = 0.18 in/day

2. Find gross application rate:
   - GPM/Vine = (inches/day * spacing)/(96.3 * hrs)
   - GPH/Vine = (GPM/Vine)/(Future DU)

   - Flow Rate = 0.18 in/day
   - Vine Spacing = 6 ft
   - Hours of Operation = 18 hrs/day
   - Design DU = 0.92
   - Future DU = 0.86
   - GPH/Vine = 0.340

3. Estimate number of emitters/vine:
   - Soil Type = Russian Loam
   - Soil Type (ft) (m)
   - Additional Lateral Movement for Drip
   - Wetted Area = 2 in
**Total Wetted Area Diameter = 7.5 ft**

**Wetted Area = 44.2 ft²**

**Wetted Area % = 92%**

Therefore, one emitter per vine will work but due to manufacturing constraints two emitters at 36" spacing will need to be used.

Emitters/Vine = 2

---

1) Select number of sets:

Netafim Uniram is a pressure compensating (PC) drip line.

Notes:

- Regulating Pressure = 7 to 58 PSI
- Minimum Pressure = 7 PSI
- Filtration Requirement = 120 mesh

**ID Options**

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**Dripper Options Data**

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**# Sets = 1 set**

**GPH/Emitter = 0.260 GPH/Emitter**

---

**Notes:**

- Netafim Uniram is a pressure compensating (PC) drip line.
- All of dripper and hose data was taken off of netafimusa.com on the Netafim Uniram technical page.

**4) Select number of sets:**

Netafim Uniram

Therefore, since none of the set options results in a GPH close to a manufacturer GPH it doesn't matter which to choose from.

---

**5) Summary:**

- **Number of Sets = 1 set**
- **GPH/Emitter = 0.260 GPH/Emitter**
- **Avg Emitter Pressure = 13 PSI**
- **GPM/100 ft = 0.0722 GPM/100 ft**
- **Nominal Flow = 0.260 GPH**
- **Nominal GPM/100 ft = 0.0722 GPM/100 ft**
- **Emitters/Vine = 2**
- **Vine Spacing = 8 ft**
- **day = 0.18 h/day**
- **GPM Emitters/Vine = [(inches/day * spacing)/(96.3 * hrs)]/(DU)**
- **By manipulating the above equation:**
- **Corrected Hr/day = 11.76 hrs/day**
- **Corrected Hr/week = 82.29 hrs/week**

---

**6) Inlet pressure calculations:**

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<th>Length (in)</th>
<th>Length (in)</th>
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Hose ID = 0.540 in
Emitter Spacing = 36 in
Longest Hose Length = 581 ft
GPH/Emitter = 0.260 GPH

Desired End Line Pressure = 13 PSI
Pressure Loss from Chart = 2.5 PSI
Required Inlet Pressure = 15.5 PSI

Note: Therefore, choose the smallest diameter drip hose because it still maintains the same DU and the pressure increase is not significant.

Now, check the pressure loss data with the data provided from the Netafim website:

![Diagram](image)

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Note: Therefore, choose the smallest diameter drip hose because it still maintains the same DU and the pressure increase is not significant.

Now compare the two different required inlet pressures:
From ITRC PLACEM4 DosBox Program = 14.6 PSI
From Netafim Uniram Technical Data = 15.5 PSI

Therefore, use the larger of the two scenarios in order to make sure you have enough pressure.

Minimum Inlet Pressure on Last Drip Hose = 15.5 PSI

7) Determine the allowable pressure change along the manifold:
   Design DU = 0.92
   Hose DU = 0.97
   Average Emitter Pressure = 13.0 PSI
   Allowable ∆P = 8.5 PSI
   Allowable ∆P = 2 * (Pavg - Pmin)
   Total Field Allowable ∆P = 9.1 PSI
   Pressure Change Hose = 5.0 PSI
   Manifold Allowable Change = 4.1 PSI

8) Manifold sizing:
   EPM/Emitter = 0.260 GPM
   EPM/Emitter = 0.0043 GPM
   Length of Field (E-W) = 1140 ft
   Spacing Between Vines = 6 ft
   Hose Lengthuphill = 559 ft
   Hose Lengthdownhill = 581 ft
   Length of Field (N-S) = 1020 ft
   Spacing Between Rows = 8 ft
   Total # of Rows = 128.5 rows
   Manifold North of Mainline = 340 ft
   Manifold South of Mainline = 680 ft
   # Rows to the North = 42.5 rows
   # Rows to the South = 86 rows
   Corrected # of Rows to North = 42

Note: The 43.5 rows North of the mainline is not possible so round down to 43 rows. This just means an extra four feet will be on the North border of the field.

Individual Hose Inlet GPM = 1.65 GPM
Total Field Flow Rate = 211.2 GPM

Manifold Sizing Inputs:
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<th>Nominal Dia (in)</th>
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</table>

Spacing Between Rows = 6 ft
Slope Between Rows = 0.039
Individual Hose Inlet GPM = 1.65 GPM
Minimum Hose Inlet Pressure = 15.5 PSI
Since the pressure regulating point (the pressure compensating emitters) is downstream of the manifold, the manifold will be designed using economics. This means the velocity of the water in the pipe is important and should not exceed 4.5 ft/sec. If it gets near that, an increase in pipe size will occur.

### Manifold Sizing for Line South of Mainline

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<td>4.78</td>
<td>-1.490</td>
<td>0.001</td>
<td>17.89</td>
<td>3.284</td>
<td>8.00</td>
<td>2.193</td>
<td>0.001</td>
<td>0.0413</td>
<td></td>
<td></td>
</tr>
<tr>
<td>199</td>
<td>3.79</td>
<td>-3.180</td>
<td>0.001</td>
<td>17.89</td>
<td>3.284</td>
<td>8.00</td>
<td>2.193</td>
<td>0.001</td>
<td>0.0413</td>
<td></td>
<td></td>
</tr>
<tr>
<td>200</td>
<td>2.80</td>
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<td>8.00</td>
<td>2.193</td>
<td>0.001</td>
<td>0.0413</td>
<td></td>
<td></td>
</tr>
<tr>
<td>201</td>
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<td>-6.560</td>
<td>0.001</td>
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<td>8.00</td>
<td>2.193</td>
<td>0.001</td>
<td>0.0413</td>
<td></td>
<td></td>
</tr>
<tr>
<td>202</td>
<td>0.82</td>
<td>-8.250</td>
<td>0.001</td>
<td>17.89</td>
<td>3.284</td>
<td>8.00</td>
<td>2.193</td>
<td>0.001</td>
<td>0.0413</td>
<td></td>
<td></td>
</tr>
<tr>
<td>203</td>
<td>-0.02</td>
<td>-9.940</td>
<td>0.001</td>
<td>17.89</td>
<td>3.284</td>
<td>8.00</td>
<td>2.193</td>
<td>0.001</td>
<td>0.0413</td>
<td></td>
<td></td>
</tr>
<tr>
<td>204</td>
<td>-1.01</td>
<td>-11.630</td>
<td>0.001</td>
<td>17.89</td>
<td>3.284</td>
<td>8.00</td>
<td>2.193</td>
<td>0.001</td>
<td>0.0413</td>
<td></td>
<td></td>
</tr>
<tr>
<td>205</td>
<td>-2.02</td>
<td>-13.320</td>
<td>0.001</td>
<td>17.89</td>
<td>3.284</td>
<td>8.00</td>
<td>2.193</td>
<td>0.001</td>
<td>0.0413</td>
<td></td>
<td></td>
</tr>
<tr>
<td>206</td>
<td>-3.03</td>
<td>-15.010</td>
<td>0.001</td>
<td>17.89</td>
<td>3.284</td>
<td>8.00</td>
<td>2.193</td>
<td>0.001</td>
<td>0.0413</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Since the pressure regulating point (the pressure compensating emitters) is downstream of the manifold, the manifold will be designed using economics. This means the velocity of the water in the pipe is important and should not exceed 4.5 ft/sec. If it gets near that, an increase in pipe size will occur.
### Mainline sizing:

> Note: Since the flushing flow rate for the field is larger than the flow rate for the irrigation needs, therefore don't flush all the drip hoses

<table>
<thead>
<tr>
<th>Point</th>
<th>Segment GPM</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>1.650</td>
</tr>
<tr>
<td>B</td>
<td>3.300</td>
</tr>
<tr>
<td>C</td>
<td>4.950</td>
</tr>
<tr>
<td>D</td>
<td>6.600</td>
</tr>
<tr>
<td>E</td>
<td>8.250</td>
</tr>
<tr>
<td>F</td>
<td>9.900</td>
</tr>
<tr>
<td>G</td>
<td>11.550</td>
</tr>
<tr>
<td>H</td>
<td>13.200</td>
</tr>
<tr>
<td>I</td>
<td>14.850</td>
</tr>
<tr>
<td>J</td>
<td>16.500</td>
</tr>
<tr>
<td>K</td>
<td>18.150</td>
</tr>
<tr>
<td>L</td>
<td>19.800</td>
</tr>
</tbody>
</table>

**Inlet Pressure to Last Hose:**

\[ 16.24 \ 

**Inlet Pressure to Manifold:**

\[ 16.16 \ 

**Manifold Sizing for Line North of Mainline**

- **C - Tee Where Mainline Meets Manifold**
- **Description**
  - **A to B**
  - **Distance Between (ft)**
  - **ID (in)**
  - **H₂ (PSI)**
  - **AE (psi)**
  - **AP (PSI)**
  - **Velocity (ft/sec)**
  - **ID** 1.5
  - **PSI** 1.5
  - **Velocity** 1.5
  - **Max Manifold GPM** 141.90 GPM
  - **Max Pressure Difference** 13.5 PSI
  - **Flush Velocity** 1.3 ft/sec
  - **Flush Q for Field** 244.48 GPM
  - **Inlet Pressure** 2.03 PSI
  - **Inlet Pressure to Field** 17.52 PSI
  - **Total Friction** 13.5 PSI
  - **Flushing Q** 1.21 GPM
  - **Flow Rate** 211.20 GPM
  - **# of L laterals** 110 laterals

### Project Details:

- **Manifold Sizing:**
  - **C - Tee Where Mainline Meets Manifold**
  - **Description**
    - **A to B** 30 ft
    - **B to C** 58 ft
  - **Flow Rate** 211.20 GPM
  - **Flush Velocity** 1.3 ft/sec
  - **Flush Q for Field** 244.48 GPM
  - **Max Manifold GPM** 141.90 GPM
  - **Max Pressure Difference** 13.5 PSI
  - **Flushing Q** 1.21 GPM
  - **Flow Rate** 211.20 GPM
  - **# of L laterals** 110 laterals

### Graphical Representation:

- Graph showing the relationship between flow rate and pressure,
- Flow rate is plotted against pressure,
- Key points and critical paths are highlighted.
<table>
<thead>
<tr>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
<th>F</th>
<th>G</th>
<th>H</th>
<th>I</th>
<th>J</th>
<th>K</th>
<th>L</th>
</tr>
</thead>
<tbody>
<tr>
<td>455</td>
<td>Field Flow Rate =</td>
<td>211.20 GPM</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>456</td>
<td>Slope Down Rows (West to East) =</td>
<td>0.02%</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>457</td>
<td>Slope Between Rows (North to South) =</td>
<td>0.03%</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>458</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>459</td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>466</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>466</td>
<td>Point</td>
<td>Point P (PSI)</td>
<td>U/S Segment Q (GPM)</td>
<td>ID (in)</td>
<td>Segment Length (ft)</td>
<td>Segment HF (PSI)</td>
<td>∆ Elev (PSI)</td>
<td>A P (PSI)</td>
<td>Velocity (ft/s)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td></td>
<td></td>
</tr>
<tr>
<td>466</td>
<td>C</td>
<td>19.55</td>
<td>211</td>
<td>10.226</td>
<td>581</td>
<td>0.0063</td>
<td>-0.0030</td>
<td>0.0106</td>
<td>0.83</td>
<td></td>
<td></td>
</tr>
<tr>
<td>466</td>
<td>B</td>
<td>19.56</td>
<td>211</td>
<td>10.226</td>
<td>30</td>
<td>-0.0033</td>
<td>0.0039</td>
<td>0.0070</td>
<td>0.83</td>
<td></td>
<td></td>
</tr>
<tr>
<td>466</td>
<td>A</td>
<td>19.57</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* Note: The pressure at Point B is the required inlet pressure to the manifold from the tables above and the pressure at Point A is pressure d/s of the filters.

11) Filtration requirements:

- Maximum Flow Rate = 211.20 GPM
- Recommended Filtration = 120 mesh

### Mesh Size Table

<table>
<thead>
<tr>
<th>Mesh Size</th>
<th>Opening Size (in)</th>
<th>mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>20</td>
<td>0.028</td>
<td>0.711</td>
</tr>
<tr>
<td>80</td>
<td>0.0071</td>
<td>0.180</td>
</tr>
<tr>
<td>100</td>
<td>0.0066</td>
<td>0.152</td>
</tr>
<tr>
<td>120</td>
<td>0.0049</td>
<td>0.124</td>
</tr>
<tr>
<td>150</td>
<td>0.0041</td>
<td>0.104</td>
</tr>
<tr>
<td>200</td>
<td>0.0034</td>
<td>0.076</td>
</tr>
</tbody>
</table>

### Media Selection Table

<table>
<thead>
<tr>
<th>Media #</th>
<th>Media Type</th>
<th>Mean Effective Media Size (mm)</th>
<th>Mean Filtration Capacity (GPM/ft²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>12</td>
<td>Round Monterey Sand</td>
<td>1.30</td>
<td>0.16 - 0.13</td>
</tr>
<tr>
<td>16</td>
<td>Round Monterey Sand</td>
<td>0.65</td>
<td>0.12 - 0.15</td>
</tr>
<tr>
<td>12</td>
<td>Crushed Granite</td>
<td>1.50</td>
<td>0.11 - 0.15</td>
</tr>
<tr>
<td>20</td>
<td>Round Monterey Sand</td>
<td>0.50</td>
<td>0.11</td>
</tr>
<tr>
<td>11</td>
<td>Crushed Granite</td>
<td>0.78</td>
<td>0.08 - 0.11</td>
</tr>
<tr>
<td>16</td>
<td>Crushed Granite</td>
<td>0.70</td>
<td>0.08 - 0.10</td>
</tr>
<tr>
<td>20</td>
<td>Crushed Granite</td>
<td>0.47</td>
<td>0.06 - 0.08</td>
</tr>
</tbody>
</table>

Therefore, use 8 Crushed Granite.

12) Size the media tanks and determine how many:

- Maximum Flow Rate = 211.20 GPM
- Irrigation System Flow Rate (GPM) = 211.20 GPM

<table>
<thead>
<tr>
<th>Number and Size (dia) of Tanks</th>
<th>Moderate Dirt Load</th>
<th>Modestly Heavy Dirt Load</th>
</tr>
</thead>
<tbody>
<tr>
<td>50</td>
<td>70</td>
<td>3.18</td>
</tr>
<tr>
<td>50</td>
<td>105</td>
<td>3.24</td>
</tr>
<tr>
<td>175 - 235</td>
<td>122 - 192</td>
<td>3.30</td>
</tr>
<tr>
<td>276 - 425</td>
<td>191 - 299</td>
<td>4.30</td>
</tr>
<tr>
<td>426 - 575</td>
<td>300 - 399</td>
<td>4.36</td>
</tr>
<tr>
<td>576 - 775</td>
<td>400 - 519</td>
<td>4.48</td>
</tr>
<tr>
<td>776 - 1025</td>
<td>540 - 719</td>
<td>5.48</td>
</tr>
</tbody>
</table>

Therefore, use four 360" sand media tanks.

13) Total dynamic head (TDH) required of the pump:

- Pressure Required Downstream of Filters = 19.57 PSI
- Dirty Media Filter Loss = 7.00 PSI
- Emergency Screen Loss = 0.50 PSI
- Manifold to Vine Height = 4.50 ft
- Manifold to Vine Height = 2.81 PSI
- Minor Losses = 3.00 PSI

Required Pump TDH = 32.89 PSI
Required Pump TDH = 32.89 ft

* Minor losses include: check valves, set valves, risers, pressure regulators, elbows, etc.
APPENDIX C

Reservoir Enlargement Calculations
Given:
- Crop: Wine Grapes
- Location: Potter Valley, Ca.
- Field Size: 110,800 ft²
- Field Length (N/S): 1020 ft
- Field Length (E/W): 1140 ft
- Vine Spacing:
  - Spacing Between Rows: 8 ft
  - Spacing Between Vines in a Row: 6 ft
- Sprinkler Spacing:
  - Spacing Between Rows: 36 ft
  - Spacing in Rows: 48 ft
- GPM/Sprinkler = 0.82
- Low Temperature: 22°F
- Wind Speed: 1 MPH
- Consecutive Days of Frost Protection = 4 days
- Hours of Frost Protection Operation = 11 hrs

Design:
1) Find the GPM/Sprinkler required:
   According to table 1-6 in the BRAE 331 textbook:
   \[ \text{GPM/Sprinkler} = \frac{\text{in/hr Application Rate}}{3.95} \]

\[ \text{in/hr Application Rate} = 22 \text{ in/hr} \]

\[ \text{Wind Speed} = 1 \text{ MPH} \]

\[ \text{Gross = Net/ DU} \]

\[ \text{Gross in/hr Needed} = \frac{0.18}{0.18} \text{ in/hr} \]

\[ \text{GPM/Sprinkler} = \frac{\text{Gross in/hr Needed}}{3.95} \]

2) Select sprinkler type:
   From Nelson Irrigation’s website:
   - Sprinkler Type = Nelson R33 Rotator Sprinkler
   - Plate Description = Gold 18
   - Nozzle Size = 9/64"
   - Desired GPM/Sprinkler = 3.95 GPM/Sprinkler

\[ \text{Average K} = 0.57\% \]

3) Find operating pressure at desired flow rate:

\[ \text{Pressure in PSI} = \frac{\text{Q}}{\text{K}} \]

\[ \text{F} = \frac{\text{Q}}{\text{K}} \]

\[ \text{Therefore, Pressure at Desired Flow Rate} = 47.14 \text{ PSI} \]

4) Find GPM/Acre:

\[ \text{GPM/Acre} = \frac{\text{Desired Flow Rate}}{3.95 \text{ GPM/Sprinkler}} \]

\[ \text{Sprinkler Spacing:} \]

\[ \text{Spacing Between Rows} = 36 \text{ ft} \]

\[ \text{Spacing in Rows} = 48 \text{ ft} \]

\[ \text{Sprinklers/Acre} = 25.2 \text{ Sprinklers/Acre} \]

\[ \text{Therefore, GPM/Acre} = 99.6 \text{ GPM/Acre} \]
5) Find hours of operation and successive days of frost:

Data from Grower:

Consecutive Days of Frost Protection = 4 days
Hours of Operation = 11 hrs/night

Therefore, Total Frost Protection Hours = 44 hrs

6) Find size of reservoir needed for frost protection

GPM/Acre = 99.6 GPM/Acre
Total Hours of Frost Protection = 44 hrs
Field Size = 25.27 acres

1 Cubic Foot = 7.48 ft³

Frost Protection Storage Needed = 6646459 gallons
Frost Protection Storage Needed = 888505 ft³

Frost Protection Storage Needed = 20.4 acre-ft

This analysis doesn't include water storage needed for irrigation because the vines don't transpire that much during frost season. When frost protection is occurring some of the water that is applied to the soil during the frost will go towards the field.

7) Find size of reservoir needed with frost protection and irrigation needs

Insurance Storage (10%) = 2.0 acre-ft
Total Storage Needed = 22.4 acre-ft

Note: This analysis has been done assuming water cannot be delivered to the reservoir during the four days of consecutive frost protection. In conclusion, Todd Farms should enlarge their current reservoir to the size specified above highlighted in yellow.
APPENDIX D

NRCS Soils Report
Custom Soil Resource Report for Mendocino County, Eastern Part and Southwestern Part of Trinity County, California
Preface

Soil surveys contain information that affects land use planning in survey areas. They highlight soil limitations that affect various land uses and provide information about the properties of the soils in the survey areas. Soil surveys are designed for many different users, including farmers, ranchers, foresters, agronomists, urban planners, community officials, engineers, developers, builders, and home buyers. Also, conservationists, teachers, students, and specialists in recreation, waste disposal, and pollution control can use the surveys to help them understand, protect, or enhance the environment.

Various land use regulations of Federal, State, and local governments may impose special restrictions on land use or land treatment. Soil surveys identify soil properties that are used in making various land use or land treatment decisions. The information is intended to help the land users identify and reduce the effects of soil limitations on various land uses. The landowner or user is responsible for identifying and complying with existing laws and regulations.

Although soil survey information can be used for general farm, local, and wider area planning, onsite investigation is needed to supplement this information in some cases. Examples include soil quality assessments (http://soils.usda.gov/sqi/) and certain conservation and engineering applications. For more detailed information, contact your local USDA Service Center (http://offices.sc.egov.usda.gov/locator/app?agency=nrcs) or your NRCS State Soil Scientist (http://soils.usda.gov/contact/state_offices/).

Great differences in soil properties can occur within short distances. Some soils are seasonally wet or subject to flooding. Some are too unstable to be used as a foundation for buildings or roads. Clayey or wet soils are poorly suited to use as septic tank absorption fields. A high water table makes a soil poorly suited to basements or underground installations.

The National Cooperative Soil Survey is a joint effort of the United States Department of Agriculture and other Federal agencies, State agencies including the Agricultural Experiment Stations, and local agencies. The Natural Resources Conservation Service (NRCS) has leadership for the Federal part of the National Cooperative Soil Survey.

Information about soils is updated periodically. Updated information is available through the NRCS Soil Data Mart Web site or the NRCS Web Soil Survey. The Soil Data Mart is the data storage site for the official soil survey information.

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    Mendocino County, Eastern Part and Southwestern Part of Trinity County,
      California.................................................................................................
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How Soil Surveys Are Made

Soil surveys are made to provide information about the soils and miscellaneous areas in a specific area. They include a description of the soils and miscellaneous areas and their location on the landscape and tables that show soil properties and limitations affecting various uses. Soil scientists observed the steepness, length, and shape of the slopes; the general pattern of drainage; the kinds of crops and native plants; and the kinds of bedrock. They observed and described many soil profiles. A soil profile is the sequence of natural layers, or horizons, in a soil. The profile extends from the surface down into the unconsolidated material in which the soil formed or from the surface down to bedrock. The unconsolidated material is devoid of roots and other living organisms and has not been changed by other biological activity.

Currently, soils are mapped according to the boundaries of major land resource areas (MLRAs). MLRAs are geographically associated land resource units that share common characteristics related to physiography, geology, climate, water resources, soils, biological resources, and land uses (USDA, 2006). Soil survey areas typically consist of parts of one or more MLRA.

The soils and miscellaneous areas in a survey area occur in an orderly pattern that is related to the geology, landforms, relief, climate, and natural vegetation of the area. Each kind of soil and miscellaneous area is associated with a particular kind of landform or with a segment of the landform. By observing the soils and miscellaneous areas in the survey area and relating their position to specific segments of the landform, a soil scientist develops a concept, or model, of how they were formed. Thus, during mapping, this model enables the soil scientist to predict with a considerable degree of accuracy the kind of soil or miscellaneous area at a specific location on the landscape.

Commonly, individual soils on the landscape merge into one another as their characteristics gradually change. To construct an accurate soil map, however, soil scientists must determine the boundaries between the soils. They can observe only a limited number of soil profiles. Nevertheless, these observations, supplemented by an understanding of the soil-vegetation-landscape relationship, are sufficient to verify predictions of the kinds of soil in an area and to determine the boundaries.

Soil scientists recorded the characteristics of the soil profiles that they studied. They noted soil color, texture, size and shape of soil aggregates, kind and amount of rock fragments, distribution of plant roots, reaction, and other features that enable them to identify soils. After describing the soils in the survey area and determining their properties, the soil scientists assigned the soils to taxonomic classes (units). Taxonomic classes are concepts. Each taxonomic class has a set of soil characteristics with precisely defined limits. The classes are used as a basis for comparison to classify soils systematically. Soil taxonomy, the system of taxonomic classification used in the United States, is based mainly on the kind and character of soil properties and the arrangement of horizons within the profile. After the soil scientists classified and named the soils in the survey area, they compared the
individual soils with similar soils in the same taxonomic class in other areas so that they could confirm data and assemble additional data based on experience and research.

The objective of soil mapping is not to delineate pure map unit components; the objective is to separate the landscape into landforms or landform segments that have similar use and management requirements. Each map unit is defined by a unique combination of soil components and/or miscellaneous areas in predictable proportions. Some components may be highly contrasting to the other components of the map unit. The presence of minor components in a map unit in no way diminishes the usefulness or accuracy of the data. The delineation of such landforms and landform segments on the map provides sufficient information for the development of resource plans. If intensive use of small areas is planned, onsite investigation is needed to define and locate the soils and miscellaneous areas.

Soil scientists make many field observations in the process of producing a soil map. The frequency of observation is dependent upon several factors, including scale of mapping, intensity of mapping, design of map units, complexity of the landscape, and experience of the soil scientist. Observations are made to test and refine the soil-landscape model and predictions and to verify the classification of the soils at specific locations. Once the soil-landscape model is refined, a significantly smaller number of measurements of individual soil properties are made and recorded. These measurements may include field measurements, such as those for color, depth to bedrock, and texture, and laboratory measurements, such as those for content of sand, silt, clay, salt, and other components. Properties of each soil typically vary from one point to another across the landscape.

Observations for map unit components are aggregated to develop ranges of characteristics for the components. The aggregated values are presented. Direct measurements do not exist for every property presented for every map unit component. Values for some properties are estimated from combinations of other properties.

While a soil survey is in progress, samples of some of the soils in the area generally are collected for laboratory analyses and for engineering tests. Soil scientists interpret the data from these analyses and tests as well as the field-observed characteristics and the soil properties to determine the expected behavior of the soils under different uses. Interpretations for all of the soils are field tested through observation of the soils in different uses and under different levels of management. Some interpretations are modified to fit local conditions, and some new interpretations are developed to meet local needs. Data are assembled from other sources, such as research information, production records, and field experience of specialists. For example, data on crop yields under defined levels of management are assembled from farm records and from field or plot experiments on the same kinds of soil.

Predictions about soil behavior are based not only on soil properties but also on such variables as climate and biological activity. Soil conditions are predictable over long periods of time, but they are not predictable from year to year. For example, soil scientists can predict with a fairly high degree of accuracy that a given soil will have a high water table within certain depths in most years, but they cannot predict that a high water table will always be at a specific level in the soil on a specific date.

After soil scientists located and identified the significant natural bodies of soil in the survey area, they drew the boundaries of these bodies on aerial photographs and identified each as a specific map unit. Aerial photographs show trees, buildings, fields, roads, and rivers, all of which help in locating boundaries accurately.
Soil Map

The soil map section includes the soil map for the defined area of interest, a list of soil map units on the map and extent of each map unit, and cartographic symbols displayed on the map. Also presented are various metadata about data used to produce the map, and a description of each soil map unit.
### MAP INFORMATION

Map Scale: 1:2,640 if printed on A size (8.5" × 11") sheet.

The soil surveys that comprise your AOI were mapped at 1:24,000.

Warning: Soil Map may not be valid at this scale.

Enlargement of maps beyond the scale of mapping can cause misunderstanding of the detail of mapping and accuracy of soil line placement. The maps do not show the small areas of contrasting soils that could have been shown at a more detailed scale.

Please rely on the bar scale on each map sheet for accurate map measurements.

Source of Map: Natural Resources Conservation Service


Coordinate System: UTM Zone 10N NAD83

This product is generated from the USDA-NRCS certified data as of the version date(s) listed below.

Soil Survey Area: Mendocino County, Eastern Part and Southwestern Part of Trinity County, California

Survey Area Data: Version 8, Jan 13, 2012

Date(s) aerial images were photographed: 6/14/2005

The orthophoto or other base map on which the soil lines were compiled and digitized probably differs from the background imagery displayed on these maps. As a result, some minor shifting of map unit boundaries may be evident.
Map Unit Legend

Mendocino County, Eastern Part and Southwestern Part of Trinity County, California (CA687)

<table>
<thead>
<tr>
<th>Map Unit Symbol</th>
<th>Map Unit Name</th>
<th>Acres in AOI</th>
<th>Percent of AOI</th>
</tr>
</thead>
<tbody>
<tr>
<td>115</td>
<td>Cole clay loam, 0 to 2 percent slopes</td>
<td>5.5</td>
<td>24.6%</td>
</tr>
<tr>
<td>128</td>
<td>Gielow sandy loam, 0 to 5 percent slopes</td>
<td>1.0</td>
<td>4.4%</td>
</tr>
<tr>
<td>188</td>
<td>Russian loam, 0 to 2 percent slopes</td>
<td>3.3</td>
<td>14.5%</td>
</tr>
<tr>
<td>190</td>
<td>Russian loam, gravelly substratum, 0 to 2 percent slopes</td>
<td>12.7</td>
<td>56.6%</td>
</tr>
<tr>
<td><strong>Totals for Area of Interest</strong></td>
<td></td>
<td><strong>22.5</strong></td>
<td><strong>100.0%</strong></td>
</tr>
</tbody>
</table>

Map Unit Descriptions

The map units delineated on the detailed soil maps in a soil survey represent the soils or miscellaneous areas in the survey area. The map unit descriptions, along with the maps, can be used to determine the composition and properties of a unit.

A map unit delineation on a soil map represents an area dominated by one or more major kinds of soil or miscellaneous areas. A map unit is identified and named according to the taxonomic classification of the dominant soils. Within a taxonomic class there are precisely defined limits for the properties of the soils. On the landscape, however, the soils are natural phenomena, and they have the characteristic variability of all natural phenomena. Thus, the range of some observed properties may extend beyond the limits defined for a taxonomic class. Areas of soils of a single taxonomic class rarely, if ever, can be mapped without including areas of other taxonomic classes. Consequently, every map unit is made up of the soils or miscellaneous areas for which it is named and some minor components that belong to taxonomic classes other than those of the major soils.

Most minor soils have properties similar to those of the dominant soil or soils in the map unit, and thus they do not affect use and management. These are called noncontrasting, or similar, components. They may or may not be mentioned in a particular map unit description. Other minor components, however, have properties and behavioral characteristics divergent enough to affect use or to require different management. These are called contrasting, or dissimilar, components. They generally are in small areas and could not be mapped separately because of the scale used. Some small areas of strongly contrasting soils or miscellaneous areas are identified by a special symbol on the maps. If included in the database for a given area, the contrasting minor components are identified in the map unit descriptions along with some characteristics of each. A few areas of minor components may not have been observed, and consequently they are not mentioned in the descriptions, especially where the pattern was so complex that it was impractical to make enough observations to identify all the soils and miscellaneous areas on the landscape.

The presence of minor components in a map unit in no way diminishes the usefulness or accuracy of the data. The objective of mapping is not to delineate pure taxonomic classes but rather to separate the landscape into landforms or landform segments that have similar use and management requirements. The delineation of such segments
on the map provides sufficient information for the development of resource plans. If intensive use of small areas is planned, however, onsite investigation is needed to define and locate the soils and miscellaneous areas.

An identifying symbol precedes the map unit name in the map unit descriptions. Each description includes general facts about the unit and gives important soil properties and qualities.

Soils that have profiles that are almost alike make up a soil series. Except for differences in texture of the surface layer, all the soils of a series have major horizons that are similar in composition, thickness, and arrangement.

Soils of one series can differ in texture of the surface layer, slope, stoniness, salinity, degree of erosion, and other characteristics that affect their use. On the basis of such differences, a soil series is divided into soil phases. Most of the areas shown on the detailed soil maps are phases of soil series. The name of a soil phase commonly indicates a feature that affects use or management. For example, Alpha silt loam, 0 to 2 percent slopes, is a phase of the Alpha series.

Some map units are made up of two or more major soils or miscellaneous areas. These map units are complexes, associations, or undifferentiated groups.

A complex consists of two or more soils or miscellaneous areas in such an intricate pattern or in such small areas that they cannot be shown separately on the maps. The pattern and proportion of the soils or miscellaneous areas are somewhat similar in all areas. Alpha-Beta complex, 0 to 6 percent slopes, is an example.

An association is made up of two or more geographically associated soils or miscellaneous areas that are shown as one unit on the maps. Because of present or anticipated uses of the map units in the survey area, it was not considered practical or necessary to map the soils or miscellaneous areas separately. The pattern and relative proportion of the soils or miscellaneous areas are somewhat similar. Alpha-Beta association, 0 to 2 percent slopes, is an example.

An undifferentiated group is made up of two or more soils or miscellaneous areas that could be mapped individually but are mapped as one unit because similar interpretations can be made for use and management. The pattern and proportion of the soils or miscellaneous areas in a mapped area are not uniform. An area can be made up of only one of the major soils or miscellaneous areas, or it can be made up of all of them. Alpha and Beta soils, 0 to 2 percent slopes, is an example.

Some surveys include miscellaneous areas. Such areas have little or no soil material and support little or no vegetation. Rock outcrop is an example.
Mendocino County, Eastern Part and Southwestern Part of Trinity County, California

115—Cole clay loam, 0 to 2 percent slopes

Map Unit Setting
Landscape: River valleys
Elevation: 50 to 1,500 feet
Mean annual precipitation: 25 to 50 inches
Mean annual air temperature: 55 to 61 degrees F
Frost-free period: 150 to 290 days

Map Unit Composition
Cole and similar soils: 85 percent
Minor components: 15 percent

Description of Cole

Setting
Landform: Alluvial fans
Landform position (two-dimensional): Footslope
Landform position (three-dimensional): Tread
Down-slope shape: Linear
Across-slope shape: Linear
Parent material: Alluvium derived from sedimentary rock

Properties and qualities
Slope: 0 to 2 percent
Depth to restrictive feature: More than 80 inches
Drainage class: Somewhat poorly drained
Capacity of the most limiting layer to transmit water (Ksat): Moderately low to moderately high (0.06 to 0.20 in/hr)
Depth to water table: About 0 inches
Frequency of flooding: None
Frequency of ponding: None
Available water capacity: High (about 9.1 inches)

Interpretive groups
Farmland classification: Prime farmland if irrigated and drained
Land capability classification (irrigated): 2w
Land capability (nonirrigated): 3w
Hydrologic Soil Group: C
Ecological site: Loamy Wet Bottomland (Annual Grass) - 1990 (R014XD100CA)

Typical profile
0 to 8 inches: Clay loam
8 to 41 inches: Silty clay
41 to 60 inches: Silty clay loam

Minor Components

Unnamed
Percent of map unit: 5 percent
Landform: Depressions
Clear lake
  Percent of map unit: 5 percent
  Landform: Basin floors

Cole
  Percent of map unit: 5 percent

128—Gielow sandy loam, 0 to 5 percent slopes

Map Unit Setting
  Landscape: Alluvial plains
  Elevation: 500 to 1,750 feet
  Mean annual precipitation: 44 inches
  Mean annual air temperature: 54 to 57 degrees F
  Frost-free period: 175 to 250 days

Map Unit Composition
  Gielow and similar soils: 85 percent
  Minor components: 15 percent

Description of Gielow

Setting
  Landform: Alluvial flats, flood plains
  Landform position (two-dimensional): Backslope
  Landform position (three-dimensional): Tread, flat
  Down-slope shape: Linear
  Across-slope shape: Linear
  Parent material: Alluvium derived from sedimentary rock

Properties and qualities
  Slope: 0 to 5 percent
  Depth to restrictive feature: More than 80 inches
  Drainage class: Somewhat poorly drained
  Capacity of the most limiting layer to transmit water (Ksat): Moderately high to high
    (0.57 to 1.98 in/hr)
  Depth to water table: About 0 inches
  Frequency of flooding: None
  Frequency of ponding: None
  Available water capacity: High (about 9.0 inches)

Interpretive groups
  Farmland classification: Prime farmland if irrigated and drained
  Land capability classification (irrigated): 2w
  Land capability (nonirrigated): 3w
  Hydrologic Soil Group: C

Typical profile
  0 to 4 inches: Sandy loam
  4 to 11 inches: Loam
  11 to 60 inches: Stratified sandy loam to sandy clay loam
Minor Components

Clear lake
  Percent of map unit: 3 percent
  Landform: Basin floors

Cole
  Percent of map unit: 3 percent

Feliz
  Percent of map unit: 3 percent

Russian
  Percent of map unit: 2 percent

Talmage
  Percent of map unit: 2 percent

Unnamed
  Percent of map unit: 2 percent

188—Russian loam, 0 to 2 percent slopes

Map Unit Setting
  Landscape: River valleys
  Elevation: 500 to 1,500 feet
  Mean annual precipitation: 37 inches
  Mean annual air temperature: 57 degrees F
  Frost-free period: 225 to 250 days

Map Unit Composition
  Russian and similar soils: 85 percent
  Minor components: 15 percent

Description of Russian

Setting
  Landform: Flood plains
  Landform position (two-dimensional): Backslope
  Landform position (three-dimensional): Tread
  Down-slope shape: Linear
  Across-slope shape: Linear
  Parent material: Alluvium derived from sedimentary rock

Properties and qualities
  Slope: 0 to 2 percent
  Depth to restrictive feature: More than 80 inches
  Drainage class: Well drained
  Capacity of the most limiting layer to transmit water (Ksat): Moderately high to high (0.57 to 1.98 in/hr)
  Depth to water table: More than 80 inches
  Frequency of flooding: None
Frequency of ponding: None  
Available water capacity: High (about 9.6 inches)

Interpretive groups  
Farmland classification: Prime farmland if irrigated  
Land capability classification (irrigated): 1  
Land capability (nonirrigated): 3c  
Hydrologic Soil Group: B

Typical profile  
0 to 38 inches: Loam  
38 to 60 inches: Stratified very fine sandy loam to silt loam

Minor Components

Unnamed  
Percent of map unit: 5 percent  
Landform: Flood plains

Cole  
Percent of map unit: 3 percent

Feliz  
Percent of map unit: 3 percent

Riverwash  
Percent of map unit: 2 percent  
Landform: Channels

Xerofluvents  
Percent of map unit: 2 percent  
Landform: Fans

190—Russian loam, gravelly substratum, 0 to 2 percent slopes

Map Unit Setting  
Landscape: River valleys  
Elevation: 400 to 1,500 feet  
Mean annual precipitation: 37 inches  
Mean annual air temperature: 57 degrees F  
Frost-free period: 225 to 250 days

Map Unit Composition  
Russian and similar soils: 85 percent  
Minor components: 15 percent

Description of Russian

Setting  
Landform: Flood plains  
Landform position (two-dimensional): Backslope  
Landform position (three-dimensional): Tread  
Down-slope shape: Linear
Across-slope shape: Linear
Parent material: Alluvium derived from sedimentary rock

**Properties and qualities**
- **Slope:** 0 to 2 percent
- **Depth to restrictive feature:** More than 80 inches
- **Drainage class:** Well drained
- **Capacity of the most limiting layer to transmit water (Ksat):** Moderately high to high (0.57 to 1.98 in/hr)
- **Depth to water table:** More than 80 inches
- **Frequency of flooding:** None
- **Frequency of ponding:** None
- **Available water capacity:** Moderate (about 6.6 inches)

**Interpretive groups**
- **Farmland classification:** Prime farmland if irrigated
- **Land capability classification (irrigated):** 2s
- **Land capability (nonirrigated):** 3s
- **Hydrologic Soil Group:** B

**Typical profile**
- **0 to 30 inches:** Loam
- **30 to 51 inches:** Stratified gravelly coarse sand to sandy loam
- **51 to 60 inches:** Stratified gravelly coarse sand to gravelly sandy loam

**Minor Components**

**Ponded areas**
- **Percent of map unit:** 5 percent
- **Landform:** Flood plains

**Cole**
- **Percent of map unit:** 3 percent

**Feliz**
- **Percent of map unit:** 3 percent

**Riverwash**
- **Percent of map unit:** 2 percent
- **Landform:** Channels

**Xerofluvents**
- **Percent of map unit:** 2 percent
- **Landform:** Flood plains
References


Glossary

Many of the terms relating to landforms, geology, and geomorphology are defined in more detail in the “National Soil Survey Handbook.”

**ABC soil**
A soil having an A, a B, and a C horizon.

**Ablation till**
Loose, relatively permeable earthy material deposited during the downwasting of nearly static glacial ice, either contained within or accumulated on the surface of the glacier.

**AC soil**
A soil having only an A and a C horizon. Commonly, such soil formed in recent alluvium or on steep, rocky slopes.

**Aeration, soil**
The exchange of air in soil with air from the atmosphere. The air in a well aerated soil is similar to that in the atmosphere; the air in a poorly aerated soil is considerably higher in carbon dioxide and lower in oxygen.

**Aggregate, soil**
Many fine particles held in a single mass or cluster. Natural soil aggregates, such as granules, blocks, or prisms, are called peds. Clods are aggregates produced by tillage or logging.

**Alkali (sodic) soil**
A soil having so high a degree of alkalinity (pH 8.5 or higher) or so high a percentage of exchangeable sodium (15 percent or more of the total exchangeable bases), or both, that plant growth is restricted.

**Alluvial cone**
A semiconical type of alluvial fan having very steep slopes. It is higher, narrower, and steeper than a fan and is composed of coarser and thicker layers of material deposited by a combination of alluvial episodes and (to a much lesser degree) landslides (debris flow). The coarsest materials tend to be concentrated at the apex of the cone.
Alluvial fan
A low, outspread mass of loose materials and/or rock material, commonly with gentle slopes. It is shaped like an open fan or a segment of a cone. The material was deposited by a stream at the place where it issues from a narrow mountain valley or upland valley or where a tributary stream is near or at its junction with the main stream. The fan is steepest near its apex, which points upstream, and slopes gently and convexly outward (downstream) with a gradual decrease in gradient.

Alluvium
Unconsolidated material, such as gravel, sand, silt, clay, and various mixtures of these, deposited on land by running water.

Alpha,alpha-dipyridyl
A compound that when dissolved in ammonium acetate is used to detect the presence of reduced iron (Fe II) in the soil. A positive reaction implies reducing conditions and the likely presence of redoximorphic features.

Animal unit month (AUM)
The amount of forage required by one mature cow of approximately 1,000 pounds weight, with or without a calf, for 1 month.

Aquic conditions
Current soil wetness characterized by saturation, reduction, and redoximorphic features.

Argillic horizon
A subsoil horizon characterized by an accumulation of illuvial clay.

Arroyo
The flat-floored channel of an ephemeral stream, commonly with very steep to vertical banks cut in unconsolidated material. It is usually dry but can be transformed into a temporary watercourse or short-lived torrent after heavy rain within the watershed.

Aspect
The direction toward which a slope faces. Also called slope aspect.

Association, soil
A group of soils or miscellaneous areas geographically associated in a characteristic repeating pattern and defined and delineated as a single map unit.

Available water capacity (available moisture capacity)
The capacity of soils to hold water available for use by most plants. It is commonly defined as the difference between the amount of soil water at field moisture capacity and the amount at wilting point. It is commonly expressed as inches of water per inch of soil. The capacity, in inches, in a 60-inch profile or to a limiting layer is expressed as:
Very low: 0 to 3  
Low: 3 to 6  
Moderate: 6 to 9  
High: 9 to 12  
Very high: More than 12

**Backslope**

The position that forms the steepest and generally linear, middle portion of a hillslope. In profile, backslopes are commonly bounded by a convex shoulder above and a concave footslope below.

**Backswamp**

A flood-plain landform. Extensive, marshy or swampy, depressed areas of flood plains between natural levees and valley sides or terraces.

**Badland**

A landscape that is intricately dissected and characterized by a very fine drainage network with high drainage densities and short, steep slopes and narrow interfluves. Badlands develop on surfaces that have little or no vegetative cover overlying unconsolidated or poorly cemented materials (clays, silts, or sandstones) with, in some cases, soluble minerals, such as gypsum or halite.

**Bajada**

A broad, gently inclined alluvial piedmont slope extending from the base of a mountain range out into a basin and formed by the lateral coalescence of a series of alluvial fans. Typically, it has a broadly undulating transverse profile, parallel to the mountain front, resulting from the convexities of component fans. The term is generally restricted to constructional slopes of intermontane basins.

**Basal area**

The area of a cross section of a tree, generally referring to the section at breast height and measured outside the bark. It is a measure of stand density, commonly expressed in square feet.

**Base saturation**

The degree to which material having cation-exchange properties is saturated with exchangeable bases (sum of Ca, Mg, Na, and K), expressed as a percentage of the total cation-exchange capacity.

**Base slope (geomorphology)**

A geomorphic component of hills consisting of the concave to linear (perpendicular to the contour) slope that, regardless of the lateral shape, forms an apron or wedge at the bottom of a hillside dominated by colluvium and slope-wash sediments (for example, slope alluvium).

**Bedding plane**

A planar or nearly planar bedding surface that visibly separates each successive layer of stratified sediment or rock (of the same or different lithology) from the preceding or following layer; a plane of deposition. It commonly marks a change
in the circumstances of deposition and may show a parting, a color difference, a change in particle size, or various combinations of these. The term is commonly applied to any bedding surface, even one that is conspicuously bent or deformed by folding.

**Bedding system**

A drainage system made by plowing, grading, or otherwise shaping the surface of a flat field. It consists of a series of low ridges separated by shallow, parallel dead furrows.

**Bedrock**

The solid rock that underlies the soil and other unconsolidated material or that is exposed at the surface.

**Bedrock-controlled topography**

A landscape where the configuration and relief of the landforms are determined or strongly influenced by the underlying bedrock.

**Bench terrace**

A raised, level or nearly level strip of earth constructed on or nearly on a contour, supported by a barrier of rocks or similar material, and designed to make the soil suitable for tillage and to prevent accelerated erosion.

**Bisequum**

Two sequences of soil horizons, each of which consists of an illuvial horizon and the overlying eluvial horizons.

**Blowout (map symbol)**

A saucer-, cup-, or trough-shaped depression formed by wind erosion on a preexisting dune or other sand deposit, especially in an area of shifting sand or loose soil or where protective vegetation is disturbed or destroyed. The adjoining accumulation of sand derived from the depression, where recognizable, is commonly included. Blowouts are commonly small.

**Borrow pit (map symbol)**

An open excavation from which soil and underlying material have been removed, usually for construction purposes.

**Bottom land**

An informal term loosely applied to various portions of a flood plain.

**Boulders**

Rock fragments larger than 2 feet (60 centimeters) in diameter.

**Breaks**

A landscape or tract of steep, rough or broken land dissected by ravines and gullies and marking a sudden change in topography.
Breast height
An average height of 4.5 feet above the ground surface; the point on a tree where
diameter measurements are ordinarily taken.

Brush management
Use of mechanical, chemical, or biological methods to make conditions favorable
for reseeding or to reduce or eliminate competition from woody vegetation and
thus allow understory grasses and forbs to recover. Brush management increases
forage production and thus reduces the hazard of erosion. It can improve the
habitat for some species of wildlife.

Butte
An isolated, generally flat-topped hill or mountain with relatively steep slopes and
talus or precipitous cliffs and characterized by summit width that is less than the
height of bounding escarpments; commonly topped by a caprock of resistant
material and representing an erosion remnant carved from flat-lying rocks.

Cable yarding
A method of moving felled trees to a nearby central area for transport to a
processing facility. Most cable yarding systems involve use of a drum, a pole, and
wire cables in an arrangement similar to that of a rod and reel used for fishing. To
reduce friction and soil disturbance, felled trees generally are reeled in while one
end is lifted or the entire log is suspended.

Calcareous soil
A soil containing enough calcium carbonate (commonly combined with
magnesium carbonate) to effervesce visibly when treated with cold, dilute
hydrochloric acid.

Caliche
A general term for a prominent zone of secondary carbonate accumulation in
surficial materials in warm, subhumid to arid areas. Caliche is formed by both
tectonic and pedologic processes. Finely crystalline calcium carbonate forms a
nearly continuous surface-coating and void-filling medium in geologic (parent)
materials. Cementation ranges from weak in nonindurated forms to very strong in
indurated forms. Other minerals (e.g., carbonates, silicate, and sulfate) may occur
as accessory cements. Most petrocalcic horizons and some calcic horizons are
caliche.

California bearing ratio (CBR)
The load-supporting capacity of a soil as compared to that of standard crushed
limestone, expressed as a ratio. First standardized in California. A soil having a
CBR of 16 supports 16 percent of the load that would be supported by standard
crushed limestone, per unit area, with the same degree of distortion.

Canopy
The leafy crown of trees or shrubs. (See Crown.)
Canyon
A long, deep, narrow valley with high, precipitous walls in an area of high local relief.

Capillary water
Water held as a film around soil particles and in tiny spaces between particles. Surface tension is the adhesive force that holds capillary water in the soil.

Catena
A sequence, or “chain,” of soils on a landscape that formed in similar kinds of parent material and under similar climatic conditions but that have different characteristics as a result of differences in relief and drainage.

Cation
An ion carrying a positive charge of electricity. The common soil cations are calcium, potassium, magnesium, sodium, and hydrogen.

Cation-exchange capacity
The total amount of exchangeable cations that can be held by the soil, expressed in terms of milliequivalents per 100 grams of soil at neutrality (pH 7.0) or at some other stated pH value. The term, as applied to soils, is synonymous with base-exchange capacity but is more precise in meaning.

Catsteps
See Terracettes.

Cement rock
Shaly limestone used in the manufacture of cement.

Channery soil material
Soil material that has, by volume, 15 to 35 percent thin, flat fragments of sandstone, shale, slate, limestone, or schist as much as 6 inches (15 centimeters) along the longest axis. A single piece is called a channer.

Chemical treatment
Control of unwanted vegetation through the use of chemicals.

Chiseling
Tillage with an implement having one or more soil-penetrating points that shatter or loosen hard, compacted layers to a depth below normal plow depth.

Cirque
A steep-walled, semicircular or crescent-shaped, half-bowl-like recess or hollow, commonly situated at the head of a glaciated mountain valley or high on the side of a mountain. It was produced by the erosive activity of a mountain glacier. It commonly contains a small round lake (tarn).
Clay

As a soil separate, the mineral soil particles less than 0.002 millimeter in diameter. As a soil textural class, soil material that is 40 percent or more clay, less than 45 percent sand, and less than 40 percent silt.

Clay depletions

See Redoximorphic features.

Clay film

A thin coating of oriented clay on the surface of a soil aggregate or lining pores or root channels. Synonyms: clay coating, clay skin.

Clay spot (map symbol)

A spot where the surface texture is silty clay or clay in areas where the surface layer of the soils in the surrounding map unit is sandy loam, loam, silt loam, or coarser.

Claypan

A dense, compact subsoil layer that contains much more clay than the overlying materials, from which it is separated by a sharply defined boundary. The layer restricts the downward movement of water through the soil. A claypan is commonly hard when dry and plastic and sticky when wet.

Climax plant community

The stabilized plant community on a particular site. The plant cover reproduces itself and does not change so long as the environment remains the same.

Coarse textured soil

Sand or loamy sand.

Cobble (or cobblestone)

A rounded or partly rounded fragment of rock 3 to 10 inches (7.6 to 25 centimeters) in diameter.

Cobbly soil material

Material that has 15 to 35 percent, by volume, rounded or partially rounded rock fragments 3 to 10 inches (7.6 to 25 centimeters) in diameter. Very cobbly soil material has 35 to 60 percent of these rock fragments, and extremely cobbly soil material has more than 60 percent.

COLE (coefficient of linear extensibility)

See Linear extensibility.

Colluvium

Unconsolidated, unsorted earth material being transported or deposited on side slopes and/or at the base of slopes by mass movement (e.g., direct gravitational action) and by local, unconcentrated runoff.
Complex slope
Irregular or variable slope. Planning or establishing terraces, diversions, and other water-control structures on a complex slope is difficult.

Complex, soil
A map unit of two or more kinds of soil or miscellaneous areas in such an intricate pattern or so small in area that it is not practical to map them separately at the selected scale of mapping. The pattern and proportion of the soils or miscellaneous areas are somewhat similar in all areas.

Concretions
See Redoximorphic features.

Conglomerate
A coarse grained, clastic sedimentary rock composed of rounded or subangular rock fragments more than 2 millimeters in diameter. It commonly has a matrix of sand and finer textured material. Conglomerate is the consolidated equivalent of gravel.

Conservation cropping system
Growing crops in combination with needed cultural and management practices. In a good conservation cropping system, the soil-improving crops and practices more than offset the effects of the soil-depleting crops and practices. Cropping systems are needed on all tilled soils. Soil-improving practices in a conservation cropping system include the use of rotations that contain grasses and legumes and the return of crop residue to the soil. Other practices include the use of green manure crops of grasses and legumes, proper tillage, adequate fertilization, and weed and pest control.

Conservation tillage
A tillage system that does not invert the soil and that leaves a protective amount of crop residue on the surface throughout the year.

Consistence, soil
Refers to the degree of cohesion and adhesion of soil material and its resistance to deformation when ruptured. Consistence includes resistance of soil material to rupture and to penetration; plasticity, toughness, and stickiness of puddled soil material; and the manner in which the soil material behaves when subject to compression. Terms describing consistence are defined in the “Soil Survey Manual.”

Contour stripcropping
Growing crops in strips that follow the contour. Strips of grass or close-growing crops are alternated with strips of clean-tilled crops or summer fallow.

Control section
The part of the soil on which classification is based. The thickness varies among different kinds of soil, but for many it is that part of the soil profile between depths of 10 inches and 40 or 80 inches.
**Coprogenous earth (sedimentary peat)**
A type of limnic layer composed predominantly of fecal material derived from aquatic animals.

**Corrosion (geomorphology)**
A process of erosion whereby rocks and soil are removed or worn away by natural chemical processes, especially by the solvent action of running water, but also by other reactions, such as hydrolysis, hydration, carbonation, and oxidation.

**Corrosion (soil survey interpretations)**
Soil-induced electrochemical or chemical action that dissolves or weakens concrete or uncoated steel.

**Cover crop**
A close-growing crop grown primarily to improve and protect the soil between periods of regular crop production, or a crop grown between trees and vines in orchards and vineyards.

**Crop residue management**
Returning crop residue to the soil, which helps to maintain soil structure, organic matter content, and fertility and helps to control erosion.

**Cropping system**
Growing crops according to a planned system of rotation and management practices.

**Cross-slope farming**
Deliberately conducting farming operations on sloping farmland in such a way that tillage is across the general slope.

**Crown**
The upper part of a tree or shrub, including the living branches and their foliage.

**Cryoturbate**
A mass of soil or other unconsolidated earthy material moved or disturbed by frost action. It is typically coarser than the underlying material.

**Cuesta**
An asymmetric ridge capped by resistant rock layers of slight or moderate dip (commonly less than 15 percent slopes); a type of homocline produced by differential erosion of interbedded resistant and weak rocks. A cuesta has a long, gentle slope on one side (dip slope) that roughly parallels the inclined beds; on the other side, it has a relatively short and steep or clifflike slope (scarp) that cuts through the tilted rocks.

**Culmination of the mean annual increment (CMAI)**
The average annual increase per acre in the volume of a stand. Computed by dividing the total volume of the stand by its age. As the stand increases in age,
the mean annual increment continues to increase until mortality begins to reduce the rate of increase. The point where the stand reaches its maximum annual rate of growth is called the culmination of the mean annual increment.

Cutbanks cave
The walls of excavations tend to cave in or slough.

Decreasers
The most heavily grazed climax range plants. Because they are the most palatable, they are the first to be destroyed by overgrazing.

Deferred grazing
Postponing grazing or resting grazing land for a prescribed period.

Delta
A body of alluvium having a surface that is fan shaped and nearly flat; deposited at or near the mouth of a river or stream where it enters a body of relatively quiet water, generally a sea or lake.

Dense layer
A very firm, massive layer that has a bulk density of more than 1.8 grams per cubic centimeter. Such a layer affects the ease of digging and can affect filling and compacting.

Depression, closed (map symbol)
A shallow, saucer-shaped area that is slightly lower on the landscape than the surrounding area and that does not have a natural outlet for surface drainage.

Depth, soil
Generally, the thickness of the soil over bedrock. Very deep soils are more than 60 inches deep over bedrock; deep soils, 40 to 60 inches; moderately deep, 20 to 40 inches; shallow, 10 to 20 inches; and very shallow, less than 10 inches.

Desert pavement
A natural, residual concentration or layer of wind-polished, closely packed gravel, boulders, and other rock fragments mantling a desert surface. It forms where wind action and sheetwash have removed all smaller particles or where rock fragments have migrated upward through sediments to the surface. It typically protects the finer grained underlying material from further erosion.

Diatomaceous earth
A geologic deposit of fine, grayish siliceous material composed chiefly or entirely of the remains of diatoms.

Dip slope
A slope of the land surface, roughly determined by and approximately conforming to the dip of the underlying bedrock.
Diversion (or diversion terrace)

A ridge of earth, generally a terrace, built to protect downslope areas by diverting runoff from its natural course.

Divided-slope farming

A form of field stripcropping in which crops are grown in a systematic arrangement of two strips, or bands, across the slope to reduce the hazard of water erosion. One strip is in a close-growing crop that provides protection from erosion, and the other strip is in a crop that provides less protection from erosion. This practice is used where slopes are not long enough to permit a full stripcropping pattern to be used.

Drainage class (natural)

Refers to the frequency and duration of wet periods under conditions similar to those under which the soil formed. Alterations of the water regime by human activities, either through drainage or irrigation, are not a consideration unless they have significantly changed the morphology of the soil. Seven classes of natural soil drainage are recognized—excessively drained, somewhat excessively drained, well drained, moderately well drained, somewhat poorly drained, poorly drained, and very poorly drained. These classes are defined in the “Soil Survey Manual.”

Drainage, surface

Runoff, or surface flow of water, from an area.

Drainageway

A general term for a course or channel along which water moves in draining an area. A term restricted to relatively small, linear depressions that at some time move concentrated water and either do not have a defined channel or have only a small defined channel.

Draw

A small stream valley that generally is shallower and more open than a ravine or gulch and that has a broader bottom. The present stream channel may appear inadequate to have cut the drainageway that it occupies.

Drift

A general term applied to all mineral material (clay, silt, sand, gravel, and boulders) transported by a glacier and deposited directly by or from the ice or transported by running water emanating from a glacier. Drift includes unstratified material (till) that forms moraines and stratified deposits that form outwash plains, eskers, kames, varves, and glaciofluvial sediments. The term is generally applied to Pleistocene glacial deposits in areas that no longer contain glaciers.

Drumlin

A low, smooth, elongated oval hill, mound, or ridge of compact till that has a core of bedrock or drift. It commonly has a blunt nose facing the direction from which the ice approached and a gentler slope tapering in the other direction. The longer axis is parallel to the general direction of glacier flow. Drumlins are products of
streamline (laminar) flow of glaciers, which molded the subglacial floor through a combination of erosion and deposition.

Duff
A generally firm organic layer on the surface of mineral soils. It consists of fallen plant material that is in the process of decomposition and includes everything from the litter on the surface to underlying pure humus.

Dune
A low mound, ridge, bank, or hill of loose, windblown granular material (generally sand), either barren and capable of movement from place to place or covered and stabilized with vegetation but retaining its characteristic shape.

Earthy fill
See Mine spoil.

Ecological site
An area where climate, soil, and relief are sufficiently uniform to produce a distinct natural plant community. An ecological site is the product of all the environmental factors responsible for its development. It is typified by an association of species that differ from those on other ecological sites in kind and/or proportion of species or in total production.

Eluviation
The movement of material in true solution or colloidal suspension from one place to another within the soil. Soil horizons that have lost material through eluviation are eluvial; those that have received material are illuvial.

Endosaturation
A type of saturation of the soil in which all horizons between the upper boundary of saturation and a depth of 2 meters are saturated.

Eolian deposit
Sand-, silt-, or clay-sized clastic material transported and deposited primarily by wind, commonly in the form of a dune or a sheet of sand or loess.

Ephemeral stream
A stream, or reach of a stream, that flows only in direct response to precipitation. It receives no long-continued supply from melting snow or other source, and its channel is above the water table at all times.

Episaturation
A type of saturation indicating a perched water table in a soil in which saturated layers are underlain by one or more unsaturated layers within 2 meters of the surface.

Erosion
The wearing away of the land surface by water, wind, ice, or other geologic agents and by such processes as gravitational creep.
Erosion (accelerated)
Erosion much more rapid than geologic erosion, mainly as a result of human or animal activities or of a catastrophe in nature, such as a fire, that exposes the surface.

Erosion (geologic)
Erosion caused by geologic processes acting over long geologic periods and resulting in the wearing away of mountains and the building up of such landscape features as flood plains and coastal plains. Synonym: natural erosion.

Erosion pavement
A surficial lag concentration or layer of gravel and other rock fragments that remains on the soil surface after sheet or rill erosion or wind has removed the finer soil particles and that tends to protect the underlying soil from further erosion.

Erosion surface
A land surface shaped by the action of erosion, especially by running water.

Escarpment
A relatively continuous and steep slope or cliff breaking the general continuity of more gently sloping land surfaces and resulting from erosion or faulting. Most commonly applied to cliffs produced by differential erosion. Synonym: scarp.

Escarpment, bedrock (map symbol)
A relatively continuous and steep slope or cliff, produced by erosion or faulting, that breaks the general continuity of more gently sloping land surfaces. Exposed material is hard or soft bedrock.

Escarpment, nonbedrock (map symbol)
A relatively continuous and steep slope or cliff, generally produced by erosion but in some places produced by faulting, that breaks the continuity of more gently sloping land surfaces. Exposed earthy material is nonsoil or very shallow soil.

Esker
A long, narrow, sinuous, steep-sided ridge of stratified sand and gravel deposited as the bed of a stream flowing in an ice tunnel within or below the ice (subglacial) or between ice walls on top of the ice of a wasting glacier and left behind as high ground when the ice melted. Eskers range in length from less than a kilometer to more than 160 kilometers and in height from 3 to 30 meters.

Extrusive rock
Igneous rock derived from deep-seated molten matter (magma) deposited and cooled on the earth’s surface.

Fallow
Cropland left idle in order to restore productivity through accumulation of moisture. Summer fallow is common in regions of limited rainfall where cereal grain is grown.
The soil is tilled for at least one growing season for weed control and decomposition of plant residue.

**Fan remnant**
A general term for landforms that are the remaining parts of older fan landforms, such as alluvial fans, that have been either dissected or partially buried.

**Fertility, soil**
The quality that enables a soil to provide plant nutrients, in adequate amounts and in proper balance, for the growth of specified plants when light, moisture, temperature, tilth, and other growth factors are favorable.

**Fibric soil material (peat)**
The least decomposed of all organic soil material. Peat contains a large amount of well preserved fiber that is readily identifiable according to botanical origin. Peat has the lowest bulk density and the highest water content at saturation of all organic soil material.

**Field moisture capacity**
The moisture content of a soil, expressed as a percentage of the oven-dry weight, after the gravitational, or free, water has drained away; the field moisture content 2 or 3 days after a soaking rain; also called normal field capacity, normal moisture capacity, or capillary capacity.

**Fill slope**
A sloping surface consisting of excavated soil material from a road cut. It commonly is on the downhill side of the road.

**Fine textured soil**
Sandy clay, silty clay, or clay.

**Firebreak**
An area cleared of flammable material to stop or help control creeping or running fires. It also serves as a line from which to work and to facilitate the movement of firefighters and equipment. Designated roads also serve as firebreaks.

**First bottom**
An obsolete, informal term loosely applied to the lowest flood-plain steps that are subject to regular flooding.

**Flaggy soil material**
Material that has, by volume, 15 to 35 percent flagstones. Very flaggy soil material has 35 to 60 percent flagstones, and extremely flaggy soil material has more than 60 percent flagstones.

**Flagstone**
A thin fragment of sandstone, limestone, slate, shale, or (rarely) schist 6 to 15 inches (15 to 38 centimeters) long.
Flood plain

The nearly level plain that borders a stream and is subject to flooding unless protected artificially.

Flood-plain landforms

A variety of constructional and erosional features produced by stream channel migration and flooding. Examples include backswamps, flood-plain splays, meanders, meander belts, meander scrolls, oxbow lakes, and natural levees.

Flood-plain splay

A fan-shaped deposit or other outspread deposit formed where an overloaded stream breaks through a levee (natural or artificial) and deposits its material (commonly coarse grained) on the flood plain.

Flood-plain step

An essentially flat, terrace-like alluvial surface within a valley that is frequently covered by floodwater from the present stream; any approximately horizontal surface still actively modified by fluvial scour and/or deposition. May occur individually or as a series of steps.

Fluvial

Of or pertaining to rivers or streams; produced by stream or river action.

Foothills

A region of steeply sloping hills that fringes a mountain range or high-plateau escarpment. The hills have relief of as much as 1,000 feet (300 meters).

Footslope

The concave surface at the base of a hillslope. A footslope is a transition zone between upslope sites of erosion and transport (shoulders and backslopes) and downslope sites of deposition (toeslopes).

Forb

Any herbaceous plant not a grass or a sedge.

Forest cover

All trees and other woody plants (underbrush) covering the ground in a forest.

Forest type

A stand of trees similar in composition and development because of given physical and biological factors by which it may be differentiated from other stands.

Fragipan

A loamy, brittle subsurface horizon low in porosity and content of organic matter and low or moderate in clay but high in silt or very fine sand. A fragipan appears cemented and restricts roots. When dry, it is hard or very hard and has a higher bulk density than the horizon or horizons above. When moist, it tends to rupture suddenly under pressure rather than to deform slowly.
Genesis, soil

The mode of origin of the soil. Refers especially to the processes or soil-forming factors responsible for the formation of the solum, or true soil, from the unconsolidated parent material.

Gilgai

Commonly, a succession of microbasins and microknolls in nearly level areas or of microvalleys and microridges parallel with the slope. Typically, the microrelief of clayey soils that shrink and swell considerably with changes in moisture content.

Glaciofluvial deposits

Material moved by glaciers and subsequently sorted and deposited by streams flowing from the melting ice. The deposits are stratified and occur in the form of outwash plains, valley trains, deltas, kames, eskers, and kame terraces.

Glaciolacustrine deposits

Material ranging from fine clay to sand derived from glaciers and deposited in glacial lakes mainly by glacial meltwater. Many deposits are bedded or laminated.

Gleyed soil

Soil that formed under poor drainage, resulting in the reduction of iron and other elements in the profile and in gray colors.

Graded stripcropping

Growing crops in strips that grade toward a protected waterway.

Grassed waterway

A natural or constructed waterway, typically broad and shallow, seeded to grass as protection against erosion. Conducts surface water away from cropland.

Gravel

Rounded or angular fragments of rock as much as 3 inches (2 millimeters to 7.6 centimeters) in diameter. An individual piece is a pebble.

Gravel pit (map symbol)

An open excavation from which soil and underlying material have been removed and used, without crushing, as a source of sand or gravel.

Gravelly soil material

Material that has 15 to 35 percent, by volume, rounded or angular rock fragments, not prominently flattened, as much as 3 inches (7.6 centimeters) in diameter.

Gravelly spot (map symbol)

A spot where the surface layer has more than 35 percent, by volume, rock fragments that are mostly less than 3 inches in diameter in an area that has less than 15 percent rock fragments.
Green manure crop (agronomy)
A soil-improving crop grown to be plowed under in an early stage of maturity or soon after maturity.

Ground water
Water filling all the unblocked pores of the material below the water table.

Gully (map symbol)
A small, steep-sided channel caused by erosion and cut in unconsolidated materials by concentrated but intermittent flow of water. The distinction between a gully and a rill is one of depth. A gully generally is an obstacle to farm machinery and is too deep to be obliterated by ordinary tillage whereas a rill is of lesser depth and can be smoothed over by ordinary tillage.

Hard bedrock
Bedrock that cannot be excavated except by blasting or by the use of special equipment that is not commonly used in construction.

Hard to reclaim
Reclamation is difficult after the removal of soil for construction and other uses. Revegetation and erosion control are extremely difficult.

Hardpan
A hardened or cemented soil horizon, or layer. The soil material is sandy, loamy, or clayey and is cemented by iron oxide, silica, calcium carbonate, or other substance.

Head slope (geomorphology)
A geomorphic component of hills consisting of a laterally concave area of a hillside, especially at the head of a drainageway. The overland waterflow is converging.

Hemic soil material (mucky peat)
Organic soil material intermediate in degree of decomposition between the less decomposed fibric material and the more decomposed sapric material.

High-residue crops
Such crops as small grain and corn used for grain. If properly managed, residue from these crops can be used to control erosion until the next crop in the rotation is established. These crops return large amounts of organic matter to the soil.

Hill
A generic term for an elevated area of the land surface, rising as much as 1,000 feet above surrounding lowlands, commonly of limited summit area and having a well defined outline. Slopes are generally more than 15 percent. The distinction between a hill and a mountain is arbitrary and may depend on local usage.
Hillslope

A generic term for the steeper part of a hill between its summit and the drainage line, valley flat, or depression floor at the base of a hill.

Horizon, soil

A layer of soil, approximately parallel to the surface, having distinct characteristics produced by soil-forming processes. In the identification of soil horizons, an uppercase letter represents the major horizons. Numbers or lowercase letters that follow represent subdivisions of the major horizons. An explanation of the subdivisions is given in the “Soil Survey Manual.” The major horizons of mineral soil are as follows:

O horizon: An organic layer of fresh and decaying plant residue.

L horizon: A layer of organic and mineral limnic materials, including coprogenous earth (sedimentary peat), diatomaceous earth, and marl.

A horizon: The mineral horizon at or near the surface in which an accumulation of humified organic matter is mixed with the mineral material. Also, a plowed surface horizon, most of which was originally part of a B horizon.

E horizon: The mineral horizon in which the main feature is loss of silicate clay, iron, aluminum, or some combination of these.

B horizon: The mineral horizon below an A horizon. The B horizon is in part a layer of transition from the overlying A to the underlying C horizon. The B horizon also has distinctive characteristics, such as (1) accumulation of clay, sesquioxides, humus, or a combination of these; (2) prismatic or blocky structure; (3) redder or browner colors than those in the A horizon; or (4) a combination of these.

C horizon: The mineral horizon or layer, excluding indurated bedrock, that is little affected by soil-forming processes and does not have the properties typical of the overlying soil material. The material of a C horizon may be either like or unlike that in which the solum formed. If the material is known to differ from that in the solum, an Arabic numeral, commonly a 2, precedes the letter C.

Cr horizon: Soft, consolidated bedrock beneath the soil.

R layer: Consolidated bedrock beneath the soil. The bedrock commonly underlies a C horizon, but it can be directly below an A or a B horizon.


W layer: A layer of water within or beneath the soil.

Humus

The well decomposed, more or less stable part of the organic matter in mineral soils.

Hydrologic soil groups

Refers to soils grouped according to their runoff potential. The soil properties that influence this potential are those that affect the minimum rate of water infiltration on a bare soil during periods after prolonged wetting when the soil is not frozen. These properties include depth to a seasonal high water table, the infiltration rate, and depth to a layer that significantly restricts the downward movement of water. The slope and the kind of plant cover are not considered but are separate factors in predicting runoff.
Igneous rock
Rock that was formed by cooling and solidification of magma and that has not been changed appreciably by weathering since its formation. Major varieties include plutonic and volcanic rock (e.g., andesite, basalt, and granite).

Illuviation
The movement of soil material from one horizon to another in the soil profile. Generally, material is removed from an upper horizon and deposited in a lower horizon.

Impervious soil
A soil through which water, air, or roots penetrate slowly or not at all. No soil is absolutely impervious to air and water all the time.

Increasers
Species in the climax vegetation that increase in amount as the more desirable plants are reduced by close grazing. Increasers commonly are the shorter plants and the less palatable to livestock.

Infiltration
The downward entry of water into the immediate surface of soil or other material, as contrasted with percolation, which is movement of water through soil layers or material.

Infiltration capacity
The maximum rate at which water can infiltrate into a soil under a given set of conditions.

Infiltration rate
The rate at which water penetrates the surface of the soil at any given instant, usually expressed in inches per hour. The rate can be limited by the infiltration capacity of the soil or the rate at which water is applied at the surface.

Intake rate
The average rate of water entering the soil under irrigation. Most soils have a fast initial rate; the rate decreases with application time. Therefore, intake rate for design purposes is not a constant but is a variable depending on the net irrigation application. The rate of water intake, in inches per hour, is expressed as follows:

Very low: Less than 0.2
Low: 0.2 to 0.4
Moderately low: 0.4 to 0.75
Moderate: 0.75 to 1.25
Moderately high: 1.25 to 1.75
High: 1.75 to 2.5
Very high: More than 2.5
Interfluve
A landform composed of the relatively undissected upland or ridge between two adjacent valleys containing streams flowing in the same general direction. An elevated area between two drainageways that sheds water to those drainageways.

Interfluve (geomorphology)
A geomorphic component of hills consisting of the uppermost, comparatively level or gently sloping area of a hill; shoulders of backwearing hillslopes can narrow the upland or can merge, resulting in a strongly convex shape.

Intermittent stream
A stream, or reach of a stream, that does not flow year-round but that is commonly dry for 3 or more months out of 12 and whose channel is generally below the local water table. It flows only during wet periods or when it receives ground-water discharge or long, continued contributions from melting snow or other surface and shallow subsurface sources.

Invaders
On range, plants that encroach into an area and grow after the climax vegetation has been reduced by grazing. Generally, plants invade following disturbance of the surface.

Iron depletions
See Redoximorphic features.

Irrigation
Application of water to soils to assist in production of crops. Methods of irrigation are:

- **Basin:** Water is applied rapidly to nearly level plains surrounded by levees or dikes.
- **Border:** Water is applied at the upper end of a strip in which the lateral flow of water is controlled by small earth ridges called border dikes, or borders.
- **Controlled flooding:** Water is released at intervals from closely spaced field ditches and distributed uniformly over the field.
- **Corrugation:** Water is applied to small, closely spaced furrows or ditches in fields of close-growing crops or in orchards so that it flows in only one direction.
- **Drip (or trickle):** Water is applied slowly and under low pressure to the surface of the soil or into the soil through such applicators as emitters, porous tubing, or perforated pipe.
- **Furrow:** Water is applied in small ditches made by cultivation implements. Furrows are used for tree and row crops.
- **Sprinkler:** Water is sprayed over the soil surface through pipes or nozzles from a pressure system.
- **Subirrigation:** Water is applied in open ditches or tile lines until the water table is raised enough to wet the soil.
- **Wild flooding:** Water, released at high points, is allowed to flow onto an area without controlled distribution.
Kame
A low mound, knob, hummock, or short irregular ridge composed of stratified sand and gravel deposited by a subglacial stream as a fan or delta at the margin of a melting glacier; by a supraglacial stream in a low place or hole on the surface of the glacier; or as a ponded deposit on the surface or at the margin of stagnant ice.

Karst (topography)
A kind of topography that formed in limestone, gypsum, or other soluble rocks by dissolution and that is characterized by closed depressions, sinkholes, caves, and underground drainage.

Knoll
A small, low, rounded hill rising above adjacent landforms.

Ksat
See Saturated hydraulic conductivity.

Lacustrine deposit
Material deposited in lake water and exposed when the water level is lowered or the elevation of the land is raised.

Lake plain
A nearly level surface marking the floor of an extinct lake filled by well sorted, generally fine textured, stratified deposits, commonly containing varves.

Lake terrace
A narrow shelf, partly cut and partly built, produced along a lakeshore in front of a scarp line of low cliffs and later exposed when the water level falls.

Landfill (map symbol)
An area of accumulated waste products of human habitation, either above or below natural ground level.

Landslide
A general, encompassing term for most types of mass movement landforms and processes involving the downslope transport and outward deposition of soil and rock materials caused by gravitational forces; the movement may or may not involve saturated materials. The speed and distance of movement, as well as the amount of soil and rock material, vary greatly.

Large stones
Rock fragments 3 inches (7.6 centimeters) or more across. Large stones adversely affect the specified use of the soil.

Lava flow (map symbol)
A solidified, commonly lobate body of rock formed through lateral, surface outpouring of molten lava from a vent or fissure.
Leaching
The removal of soluble material from soil or other material by percolating water.

Levee (map symbol)
An embankment that confines or controls water, especially one built along the banks of a river to prevent overflow onto lowlands.

Linear extensibility
Refers to the change in length of an unconfined clod as moisture content is decreased from a moist to a dry state. Linear extensibility is used to determine the shrink-swell potential of soils. It is an expression of the volume change between the water content of the clod at $\frac{1}{3}$- or $\frac{1}{10}$-bar tension (33kPa or 10kPa tension) and oven dryness. Volume change is influenced by the amount and type of clay minerals in the soil. The volume change is the percent change for the whole soil. If it is expressed as a fraction, the resulting value is COLE, coefficient of linear extensibility.

Liquid limit
The moisture content at which the soil passes from a plastic to a liquid state.

Loam
Soil material that is 7 to 27 percent clay particles, 28 to 50 percent silt particles, and less than 52 percent sand particles.

Loess
Material transported and deposited by wind and consisting dominantly of silt-sized particles.

Low strength
The soil is not strong enough to support loads.

Low-residue crops
Such crops as corn used for silage, peas, beans, and potatoes. Residue from these crops is not adequate to control erosion until the next crop in the rotation is established. These crops return little organic matter to the soil.

Marl
An earthy, unconsolidated deposit consisting chiefly of calcium carbonate mixed with clay in approximately equal proportions; formed primarily under freshwater lacustrine conditions but also formed in more saline environments.

Marsh or swamp (map symbol)
A water-saturated, very poorly drained area that is intermittently or permanently covered by water. Sedges, cattails, and rushes are the dominant vegetation in marshes, and trees or shrubs are the dominant vegetation in swamps. Not used in map units where the named soils are poorly drained or very poorly drained.
Mass movement
A generic term for the dislodgment and downslope transport of soil and rock material as a unit under direct gravitational stress.

Masses
See Redoximorphic features.

Meander belt
The zone within which migration of a meandering channel occurs; the flood-plain area included between two imaginary lines drawn tangential to the outer bends of active channel loops.

Meander scar
A crescent-shaped, concave or linear mark on the face of a bluff or valley wall, produced by the lateral erosion of a meandering stream that impinged upon and undercut the bluff.

Meander scroll
One of a series of long, parallel, close-fitting, crescent-shaped ridges and troughs formed along the inner bank of a stream meander as the channel migrated laterally down-valley and toward the outer bank.

Mechanical treatment
Use of mechanical equipment for seeding, brush management, and other management practices.

Medium textured soil
Very fine sandy loam, loam, silt loam, or silt.

Mesa
A broad, nearly flat topped and commonly isolated landmass bounded by steep slopes or precipitous cliffs and capped by layers of resistant, nearly horizontal rocky material. The summit width is characteristically greater than the height of the bounding escarpments.

Metamorphic rock
Rock of any origin altered in mineralogical composition, chemical composition, or structure by heat, pressure, and movement at depth in the earth’s crust. Nearly all such rocks are crystalline.

Mine or quarry (map symbol)
An open excavation from which soil and underlying material have been removed and in which bedrock is exposed. Also denotes surface openings to underground mines.

Mine spoil
An accumulation of displaced earthy material, rock, or other waste material removed during mining or excavation. Also called earthy fill.
Mineral soil
Soil that is mainly mineral material and low in organic material. Its bulk density is more than that of organic soil.

Minimum tillage
Only the tillage essential to crop production and prevention of soil damage.

Miscellaneous area
A kind of map unit that has little or no natural soil and supports little or no vegetation.

Miscellaneous water (map symbol)
Small, constructed bodies of water that are used for industrial, sanitary, or mining applications and that contain water most of the year.

Moderately coarse textured soil
Coarse sandy loam, sandy loam, or fine sandy loam.

Moderately fine textured soil
Clay loam, sandy clay loam, or silty clay loam.

Mollic epipedon
A thick, dark, humus-rich surface horizon (or horizons) that has high base saturation and pedogenic soil structure. It may include the upper part of the subsoil.

Moraine
In terms of glacial geology, a mound, ridge, or other topographically distinct accumulation of unsorted, unstratified drift, predominantly till, deposited primarily by the direct action of glacial ice in a variety of landforms. Also, a general term for a landform composed mainly of till (except for kame moraines, which are composed mainly of stratified outwash) that has been deposited by a glacier. Some types of moraines are disintegration, end, ground, kame, lateral, recessional, and terminal.

Morphology, soil
The physical makeup of the soil, including the texture, structure, porosity, consistence, color, and other physical, mineral, and biological properties of the various horizons, and the thickness and arrangement of those horizons in the soil profile.

Mottling, soil
Irregular spots of different colors that vary in number and size. Descriptive terms are as follows: abundance—few, common, and many; size—fine, medium, and coarse; and contrast—faint, distinct, and prominent. The size measurements are of the diameter along the greatest dimension. Fine indicates less than 5 millimeters (about 0.2 inch); medium, from 5 to 15 millimeters (about 0.2 to 0.6 inch); and coarse, more than 15 millimeters (about 0.6 inch).
Mountain
A generic term for an elevated area of the land surface, rising more than 1,000 feet (300 meters) above surrounding lowlands, commonly of restricted summit area (relative to a plateau) and generally having steep sides. A mountain can occur as a single, isolated mass or in a group forming a chain or range. Mountains are formed primarily by tectonic activity and/or volcanic action but can also be formed by differential erosion.

Muck
Dark, finely divided, well decomposed organic soil material. (See Sapric soil material.)

Mucky peat
See Hemic soil material.

Mudstone
A blocky or massive, fine grained sedimentary rock in which the proportions of clay and silt are approximately equal. Also, a general term for such material as clay, silt, claystone, siltstone, shale, and argillite and that should be used only when the amounts of clay and silt are not known or cannot be precisely identified.

Munsell notation
A designation of color by degrees of three simple variables—hue, value, and chroma. For example, a notation of 10YR 6/4 is a color with hue of 10YR, value of 6, and chroma of 4.

Natric horizon
A special kind of argillic horizon that contains enough exchangeable sodium to have an adverse effect on the physical condition of the subsoil.

Neutral soil
A soil having a pH value of 6.6 to 7.3. (See Reaction, soil.)

Nodules
See Redoximorphic features.

Nose slope (geomorphology)
A geomorphic component of hills consisting of the projecting end (laterally convex area) of a hillside. The overland waterflow is predominantly divergent. Nose slopes consist dominantly of colluvium and slope-wash sediments (for example, slope alluvium).

Nutrient, plant
Any element taken in by a plant essential to its growth. Plant nutrients are mainly nitrogen, phosphorus, potassium, calcium, magnesium, sulfur, iron, manganese, copper, boron, and zinc obtained from the soil and carbon, hydrogen, and oxygen obtained from the air and water.
Organic matter

Plant and animal residue in the soil in various stages of decomposition. The content of organic matter in the surface layer is described as follows:

Very low: Less than 0.5 percent
Low: 0.5 to 1.0 percent
Moderately low: 1.0 to 2.0 percent
Moderate: 2.0 to 4.0 percent
High: 4.0 to 8.0 percent
Very high: More than 8.0 percent

Outwash

Stratified and sorted sediments (chiefly sand and gravel) removed or “washed out” from a glacier by meltwater streams and deposited in front of or beyond the end moraine or the margin of a glacier. The coarser material is deposited nearer to the ice.

Outwash plain

An extensive lowland area of coarse textured glaciofluvial material. An outwash plain is commonly smooth; where pitted, it generally is low in relief.

Paleoterrace

An erosional remnant of a terrace that retains the surface form and alluvial deposits of its origin but was not emplaced by, and commonly does not grade to, a present-day stream or drainage network.

Pan

A compact, dense layer in a soil that impedes the movement of water and the growth of roots. For example, hardpan, fragipan, claypan, plowpan, and traffic pan.

Parent material

The unconsolidated organic and mineral material in which soil forms.

Peat

Unconsolidated material, largely undecomposed organic matter, that has accumulated under excess moisture. (See Fibric soil material.)

Ped

An individual natural soil aggregate, such as a granule, a prism, or a block.

Pedisediment

A layer of sediment, eroded from the shoulder and backslope of an erosional slope, that lies on and is being (or was) transported across a gently sloping erosional surface at the foot of a receding hill or mountain slope.
Pedon

The smallest volume that can be called “a soil.” A pedon is three dimensional and large enough to permit study of all horizons. Its area ranges from about 10 to 100 square feet (1 square meter to 10 square meters), depending on the variability of the soil.

Percolation

The movement of water through the soil.

Perennial water (map symbol)

Small, natural or constructed lakes, ponds, or pits that contain water most of the year.

Permafrost

Ground, soil, or rock that remains at or below 0 degrees C for at least 2 years. It is defined on the basis of temperature and is not necessarily frozen.

pH value

A numerical designation of acidity and alkalinity in soil. (See Reaction, soil.)

Phase, soil

A subdivision of a soil series based on features that affect its use and management, such as slope, stoniness, and flooding.

Piping

Formation of subsurface tunnels or pipelike cavities by water moving through the soil.

Pitting

Pits caused by melting around ice. They form on the soil after plant cover is removed.

Plastic limit

The moisture content at which a soil changes from semisolid to plastic.

Plasticity index

The numerical difference between the liquid limit and the plastic limit; the range of moisture content within which the soil remains plastic.

Plateau (geomorphology)

A comparatively flat area of great extent and elevation; specifically, an extensive land region that is considerably elevated (more than 100 meters) above the adjacent lower lying terrain, is commonly limited on at least one side by an abrupt descent, and has a flat or nearly level surface. A comparatively large part of a plateau surface is near summit level.
Playa
The generally dry and nearly level lake plain that occupies the lowest parts of closed depressions, such as those on intermontane basin floors. Temporary flooding occurs primarily in response to precipitation and runoff. Playa deposits are fine grained and may or may not have a high water table and saline conditions.

Plinthite
The sesquioxide-rich, humus-poor, highly weathered mixture of clay with quartz and other diluents. It commonly appears as red mottles, usually in platy, polygonal, or reticulate patterns. Plinthite changes irreversibly to an ironstone hardpan or to irregular aggregates on repeated wetting and drying, especially if it is exposed also to heat from the sun. In a moist soil, plinthite can be cut with a spade. It is a form of laterite.

Plowpan
A compacted layer formed in the soil directly below the plowed layer.

Ponding
Standing water on soils in closed depressions. Unless the soils are artificially drained, the water can be removed only by percolation or evapotranspiration.

Poorly graded
Refers to a coarse grained soil or soil material consisting mainly of particles of nearly the same size. Because there is little difference in size of the particles, density can be increased only slightly by compaction.

Pore linings
See Redoximorphic features.

Potential native plant community
See Climax plant community.

Potential rooting depth (effective rooting depth)
Depth to which roots could penetrate if the content of moisture in the soil were adequate. The soil has no properties restricting the penetration of roots to this depth.

Prescribed burning
Deliberately burning an area for specific management purposes, under the appropriate conditions of weather and soil moisture and at the proper time of day.

Productivity, soil
The capability of a soil for producing a specified plant or sequence of plants under specific management.

Profile, soil
A vertical section of the soil extending through all its horizons and into the parent material.
Proper grazing use

Grazing at an intensity that maintains enough cover to protect the soil and maintain or improve the quantity and quality of the desirable vegetation. This practice increases the vigor and reproduction capacity of the key plants and promotes the accumulation of litter and mulch necessary to conserve soil and water.

Rangeland

Land on which the potential natural vegetation is predominantly grasses, grasslike plants, forbs, or shrubs suitable for grazing or browsing. It includes natural grasslands, savannas, many wetlands, some deserts, tundras, and areas that support certain forb and shrub communities.

Reaction, soil

A measure of acidity or alkalinity of a soil, expressed as pH values. A soil that tests to pH 7.0 is described as precisely neutral in reaction because it is neither acid nor alkaline. The degrees of acidity or alkalinity, expressed as pH values, are:

- *Ultra acid*: Less than 3.5
- *Extremely acid*: 3.5 to 4.4
- *Very strongly acid*: 4.5 to 5.0
- *Strongly acid*: 5.1 to 5.5
- *Moderately acid*: 5.6 to 6.0
- *Slightly acid*: 6.1 to 6.5
- *Neutral*: 6.6 to 7.3
- *Slightly alkaline*: 7.4 to 7.8
- *Moderately alkaline*: 7.9 to 8.4
- *Strongly alkaline*: 8.5 to 9.0
- *Very strongly alkaline*: 9.1 and higher

Red beds

Sedimentary strata that are mainly red and are made up largely of sandstone and shale.

Redoximorphic concentrations

See Redoximorphic features.

Redoximorphic depletions

See Redoximorphic features.

Redoximorphic features

Redoximorphic features are associated with wetness and result from alternating periods of reduction and oxidation of iron and manganese compounds in the soil. Reduction occurs during saturation with water, and oxidation occurs when the soil is not saturated. Characteristic color patterns are created by these processes. The reduced iron and manganese ions may be removed from a soil if vertical or lateral fluxes of water occur, in which case there is no iron or manganese precipitation in that soil. Wherever the iron and manganese are oxidized and precipitated, they
form either soft masses or hard concretions or nodules. Movement of iron and manganese as a result of redoximorphic processes in a soil may result in redoximorphic features that are defined as follows:

1. Redoximorphic concentrations.—These are zones of apparent accumulation of iron-manganese oxides, including:
   A. Nodules and concretions, which are cemented bodies that can be removed from the soil intact. Concretions are distinguished from nodules on the basis of internal organization. A concretion typically has concentric layers that are visible to the naked eye. Nodules do not have visible organized internal structure; and
   B. Masses, which are noncemented concentrations of substances within the soil matrix; and
   C. Pore linings, i.e., zones of accumulation along pores that may be either coatings on pore surfaces or impregnations from the matrix adjacent to the pores.

2. Redoximorphic depletions.—These are zones of low chroma (chromas less than those in the matrix) where either iron-manganese oxides alone or both iron-manganese oxides and clay have been stripped out, including:
   A. Iron depletions, i.e., zones that contain low amounts of iron and manganese oxides but have a clay content similar to that of the adjacent matrix; and
   B. Clay depletions, i.e., zones that contain low amounts of iron, manganese, and clay (often referred to as silt coatings or skeletans).

3. Reduced matrix.—This is a soil matrix that has low chroma in situ but undergoes a change in hue or chroma within 30 minutes after the soil material has been exposed to air.

**Reduced matrix**

See Redoximorphic features.

**Regolith**

All unconsolidated earth materials above the solid bedrock. It includes material weathered in place from all kinds of bedrock and alluvial, glacial, eolian, lacustrine, and pyroclastic deposits.

**Relief**

The relative difference in elevation between the upland summits and the lowlands or valleys of a given region.

**Residuum (residual soil material)**

Unconsolidated, weathered or partly weathered mineral material that accumulated as bedrock disintegrated in place.

**Rill**

A very small, steep-sided channel resulting from erosion and cut in unconsolidated materials by concentrated but intermittent flow of water. A rill generally is not an obstacle to wheeled vehicles and is shallow enough to be smoothed over by ordinary tillage.
Riser

The vertical or steep side slope (e.g., escarpment) of terraces, flood-plain steps, or other stepped landforms; commonly a recurring part of a series of natural, steplike landforms, such as successive stream terraces.

Road cut

A sloping surface produced by mechanical means during road construction. It is commonly on the uphill side of the road.

Rock fragments

Rock or mineral fragments having a diameter of 2 millimeters or more; for example, pebbles, cobbles, stones, and boulders.

Rock outcrop (map symbol)

An exposure of bedrock at the surface of the earth. Not used where the named soils of the surrounding map unit are shallow over bedrock or where “Rock outcrop” is a named component of the map unit.

Root zone

The part of the soil that can be penetrated by plant roots.

Runoff

The precipitation discharged into stream channels from an area. The water that flows off the surface of the land without sinking into the soil is called surface runoff. Water that enters the soil before reaching surface streams is called ground-water runoff or seepage flow from ground water.

Saline soil

A soil containing soluble salts in an amount that impairs growth of plants. A saline soil does not contain excess exchangeable sodium.

Saline spot (map symbol)

An area where the surface layer has an electrical conductivity of 8 mmhos/cm more than the surface layer of the named soils in the surrounding map unit. The surface layer of the surrounding soils has an electrical conductivity of 2 mmhos/cm or less.

Sand

As a soil separate, individual rock or mineral fragments from 0.05 millimeter to 2.0 millimeters in diameter. Most sand grains consist of quartz. As a soil textural class, a soil that is 85 percent or more sand and not more than 10 percent clay.

Sandstone

Sedimentary rock containing dominantly sand-sized particles.
Sandy spot (map symbol)
A spot where the surface layer is loamy fine sand or coarser in areas where the surface layer of the named soils in the surrounding map unit is very fine sandy loam or finer.

Sapric soil material (muck)
The most highly decomposed of all organic soil material. Muck has the least amount of plant fiber, the highest bulk density, and the lowest water content at saturation of all organic soil material.

Saturated hydraulic conductivity (Ksat)
The ease with which pores of a saturated soil transmit water. Formally, the proportionality coefficient that expresses the relationship of the rate of water movement to hydraulic gradient in Darcy’s Law, a law that describes the rate of water movement through porous media. Commonly abbreviated as “Ksat.” Terms describing saturated hydraulic conductivity are:

*Very high*: 100 or more micrometers per second (14.17 or more inches per hour)

*High*: 10 to 100 micrometers per second (1.417 to 14.17 inches per hour)

*Moderately high*: 1 to 10 micrometers per second (0.1417 inch to 1.417 inches per hour)

*Moderately low*: 0.1 to 1 micrometer per second (0.01417 to 0.1417 inch per hour)

*Low*: 0.01 to 0.1 micrometer per second (0.001417 to 0.01417 inch per hour)

*Very low*: Less than 0.01 micrometer per second (less than 0.001417 inch per hour).

To convert inches per hour to micrometers per second, multiply inches per hour by 7.0572. To convert micrometers per second to inches per hour, multiply micrometers per second by 0.1417.

Saturation
Wetness characterized by zero or positive pressure of the soil water. Under conditions of saturation, the water will flow from the soil matrix into an unlined auger hole.

Scarification
The act of abrading, scratching, loosening, crushing, or modifying the surface to increase water absorption or to provide a more tillable soil.

Sedimentary rock
A consolidated deposit of clastic particles, chemical precipitates, or organic remains accumulated at or near the surface of the earth under normal low temperature and pressure conditions. Sedimentary rocks include consolidated equivalents of alluvium, colluvium, drift, and eolian, lacustrine, and marine deposits. Examples are sandstone, siltstone, mudstone, claystone, shale, conglomerate, limestone, dolomite, and coal.

Sequum
A sequence consisting of an illuvial horizon and the overlying eluvial horizon. (See Eluviation.)
Series, soil
A group of soils that have profiles that are almost alike, except for differences in texture of the surface layer. All the soils of a series have horizons that are similar in composition, thickness, and arrangement.

Severely eroded spot (map symbol)
An area where, on the average, 75 percent or more of the original surface layer has been lost because of accelerated erosion. Not used in map units in which “severely eroded,” “very severely eroded,” or “gullied” is part of the map unit name.

Shale
Sedimentary rock that formed by the hardening of a deposit of clay, silty clay, or silty clay loam and that has a tendency to split into thin layers.

Sheet erosion
The removal of a fairly uniform layer of soil material from the land surface by the action of rainfall and surface runoff.

Short, steep slope (map symbol)
A narrow area of soil having slopes that are at least two slope classes steeper than the slope class of the surrounding map unit.

Shoulder
The convex, erosional surface near the top of a hillslope. A shoulder is a transition from summit to backslope.

Shrink-swell
The shrinking of soil when dry and the swelling when wet. Shrinking and swelling can damage roads, dams, building foundations, and other structures. It can also damage plant roots.

Shrub-coppice dune
A small, streamlined dune that forms around brush and clump vegetation.

Side slope (geomorphology)
A geomorphic component of hills consisting of a laterally planar area of a hillside. The overland waterflow is predominantly parallel. Side slopes are dominantly colluvium and slope-wash sediments.

Silica
A combination of silicon and oxygen. The mineral form is called quartz.

Silica-sesquioxide ratio
The ratio of the number of molecules of silica to the number of molecules of alumina and iron oxide. The more highly weathered soils or their clay fractions in warm-temperate, humid regions, and especially those in the tropics, generally have a low ratio.
Silt

As a soil separate, individual mineral particles that range in diameter from the upper limit of clay (0.002 millimeter) to the lower limit of very fine sand (0.05 millimeter). As a soil textural class, soil that is 80 percent or more silt and less than 12 percent clay.

Siltstone

An indurated silt having the texture and composition of shale but lacking its fine lamination or fissility; a massive mudstone in which silt predominates over clay.

Similar soils

Soils that share limits of diagnostic criteria, behave and perform in a similar manner, and have similar conservation needs or management requirements for the major land uses in the survey area.

Sinkhole (map symbol)

A closed, circular or elliptical depression, commonly funnel shaped, characterized by subsurface drainage and formed either by dissolution of the surface of underlying bedrock (e.g., limestone, gypsum, or salt) or by collapse of underlying caves within bedrock. Complexes of sinkholes in carbonate-rock terrain are the main components of karst topography.

Site index

A designation of the quality of a forest site based on the height of the dominant stand at an arbitrarily chosen age. For example, if the average height attained by dominant and codominant trees in a fully stocked stand at the age of 50 years is 75 feet, the site index is 75.

Slickensides (pedogenic)

Grooved, striated, and/or glossy (shiny) slip faces on structural peds, such as wedges; produced by shrink-swell processes, most commonly in soils that have a high content of expansive clays.

Slide or slip (map symbol)

A prominent landform scar or ridge caused by fairly recent mass movement or descent of earthy material resulting from failure of earth or rock under shear stress along one or several surfaces.

Slope

The inclination of the land surface from the horizontal. Percentage of slope is the vertical distance divided by horizontal distance, then multiplied by 100. Thus, a slope of 20 percent is a drop of 20 feet in 100 feet of horizontal distance.

Slope alluvium

Sediment gradually transported down the slopes of mountains or hills primarily by nonchannel alluvial processes (i.e., slope-wash processes) and characterized by particle sorting. Lateral particle sorting is evident on long slopes. In a profile sequence, sediments may be distinguished by differences in size and/or specific gravity of rock fragments and may be separated by stone lines. Burnished peds
and sorting of rounded or subrounded pebbles or cobbles distinguish these materials from unsorted colluvial deposits.

**Slow refill**

The slow filling of ponds, resulting from restricted water transmission in the soil.

**Slow water movement**

Restricted downward movement of water through the soil. See Saturated hydraulic conductivity.

**Sodic (alkali) soil**

A soil having so high a degree of alkalinity (pH 8.5 or higher) or so high a percentage of exchangeable sodium (15 percent or more of the total exchangeable bases), or both, that plant growth is restricted.

**Sodic spot (map symbol)**

An area where the surface layer has a sodium adsorption ratio that is at least 10 more than that of the surface layer of the named soils in the surrounding map unit. The surface layer of the surrounding soils has a sodium adsorption ratio of 5 or less.

**Sodicity**

The degree to which a soil is affected by exchangeable sodium. Sodicity is expressed as a sodium adsorption ratio (SAR) of a saturation extract, or the ratio of Na\(^+\) to Ca\(^{++}\) + Mg\(^{++}\). The degrees of sodicity and their respective ratios are:

- **Slight**: Less than 13:1
- **Moderate**: 13-30:1
- **Strong**: More than 30:1

**Sodium adsorption ratio (SAR)**

A measure of the amount of sodium (Na) relative to calcium (Ca) and magnesium (Mg) in the water extract from saturated soil paste. It is the ratio of the Na concentration divided by the square root of one-half of the Ca + Mg concentration.

**Soft bedrock**

Bedrock that can be excavated with trenching machines, backhoes, small rippers, and other equipment commonly used in construction.

**Soil**

A natural, three-dimensional body at the earth’s surface. It is capable of supporting plants and has properties resulting from the integrated effect of climate and living matter acting on earthy parent material, as conditioned by relief and by the passage of time.

**Soil separates**

Mineral particles less than 2 millimeters in equivalent diameter and ranging between specified size limits. The names and sizes, in millimeters, of separates recognized in the United States are as follows:
Very coarse sand: 2.0 to 1.0
Coarse sand: 1.0 to 0.5
Medium sand: 0.5 to 0.25
Fine sand: 0.25 to 0.10
Very fine sand: 0.10 to 0.05
Silt: 0.05 to 0.002
Clay: Less than 0.002

Solum
The upper part of a soil profile, above the C horizon, in which the processes of soil formation are active. The solum in soil consists of the A, E, and B horizons. Generally, the characteristics of the material in these horizons are unlike those of the material below the solum. The living roots and plant and animal activities are largely confined to the solum.

Spoil area (map symbol)
A pile of earthy materials, either smoothed or uneven, resulting from human activity.

Stone line
In a vertical cross section, a line formed by scattered fragments or a discrete layer of angular and subangular rock fragments (commonly a gravel- or cobble-sized lag concentration) that formerly was draped across a topographic surface and was later buried by additional sediments. A stone line generally caps material that was subject to weathering, soil formation, and erosion before burial. Many stone lines seem to be buried erosion pavements, originally formed by sheet and rill erosion across the land surface.

Stones
Rock fragments 10 to 24 inches (25 to 60 centimeters) in diameter if rounded or 15 to 24 inches (38 to 60 centimeters) in length if flat.

Stony
Refers to a soil containing stones in numbers that interfere with or prevent tillage.

Stony spot (map symbol)
A spot where 0.01 to 0.1 percent of the soil surface is covered by rock fragments that are more than 10 inches in diameter in areas where the surrounding soil has no surface stones.

Strath terrace
A type of stream terrace; formed as an erosional surface cut on bedrock and thinly mantled with stream deposits (alluvium).

Stream terrace
One of a series of platforms in a stream valley, flanking and more or less parallel to the stream channel, originally formed near the level of the stream; represents
the remnants of an abandoned flood plain, stream bed, or valley floor produced during a former state of fluvial erosion or deposition.

**Stripcropping**
Growing crops in a systematic arrangement of strips or bands that provide vegetative barriers to wind erosion and water erosion.

**Structure, soil**
The arrangement of primary soil particles into compound particles or aggregates. The principal forms of soil structure are:
- **Platy:** Flat and laminated
- **Prismatic:** Vertically elongated and having flat tops
- **Columnar:** Vertically elongated and having rounded tops
- **Angular blocky:** Having faces that intersect at sharp angles (planes)
- **Subangular blocky:** Having subrounded and planar faces (no sharp angles)
- **Granular:** Small structural units with curved or very irregular faces

Structureless soil horizons are defined as follows:
- **Single grained:** Entirely noncoherent (each grain by itself), as in loose sand
- **Massive:** Occurring as a coherent mass

**Stubble mulch**
Stubble or other crop residue left on the soil or partly worked into the soil. It protects the soil from wind erosion and water erosion after harvest, during preparation of a seedbed for the next crop, and during the early growing period of the new crop.

**Subsoil**
Technically, the B horizon; roughly, the part of the solum below plow depth.

**Subsoiling**
Tilling a soil below normal plow depth, ordinarily to shatter a hardpan or claypan.

**Substratum**
The part of the soil below the solum.

**Subsurface layer**
Any surface soil horizon (A, E, AB, or EB) below the surface layer.

**Summer fallow**
The tillage of uncropped land during the summer to control weeds and allow storage of moisture in the soil for the growth of a later crop. A practice common in semiarid regions, where annual precipitation is not enough to produce a crop every year. Summer fallow is frequently practiced before planting winter grain.
Summit
The topographically highest position of a hillslope. It has a nearly level (planar or only slightly convex) surface.

Surface layer
The soil ordinarily moved in tillage, or its equivalent in uncultivated soil, ranging in depth from 4 to 10 inches (10 to 25 centimeters). Frequently designated as the “plow layer,” or the “Ap horizon.”

Surface soil
The A, E, AB, and EB horizons, considered collectively. It includes all subdivisions of these horizons.

Talus
Rock fragments of any size or shape (commonly coarse and angular) derived from and lying at the base of a cliff or very steep rock slope. The accumulated mass of such loose broken rock formed chiefly by falling, rolling, or sliding.

Taxadjuncts
Soils that cannot be classified in a series recognized in the classification system. Such soils are named for a series they strongly resemble and are designated as taxadjuncts to that series because they differ in ways too small to be of consequence in interpreting their use and behavior. Soils are recognized as taxadjuncts only when one or more of their characteristics are slightly outside the range defined for the family of the series for which the soils are named.

Terminal moraine
An end moraine that marks the farthest advance of a glacier. It typically has the form of a massive arcuate or concentric ridge, or complex of ridges, and is underlain by till and other types of drift.

Terrace (conservation)
An embankment, or ridge, constructed across sloping soils on the contour or at a slight angle to the contour. The terrace intercepts surface runoff so that water soaks into the soil or flows slowly to a prepared outlet. A terrace in a field generally is built so that the field can be farmed. A terrace intended mainly for drainage has a deep channel that is maintained in permanent sod.

Terrace (geomorphology)
A steplike surface, bordering a valley floor or shoreline, that represents the former position of a flood plain, lake, or seashore. The term is usually applied both to the relatively flat summit surface (tread) that was cut or built by stream or wave action and to the steeper descending slope (scarp or riser) that has graded to a lower base level of erosion.

Terracettes
Small, irregular steplike forms on steep hillslopes, especially in pasture, formed by creep or erosion of surficial materials that may be induced or enhanced by trampling of livestock, such as sheep or cattle.
Texture, soil

The relative proportions of sand, silt, and clay particles in a mass of soil. The basic textural classes, in order of increasing proportion of fine particles, are sand, loamy sand, sandy loam, loam, silt, sandy clay loam, clay loam, silty clay loam, sandy clay, silty clay, and clay. The sand, loamy sand, and sandy loam classes may be further divided by specifying “coarse,” “fine,” or “very fine.”

Thin layer

Otherwise suitable soil material that is too thin for the specified use.

Till

Dominantly unsorted and nonstratified drift, generally unconsolidated and deposited directly by a glacier without subsequent reworking by meltwater, and consisting of a heterogeneous mixture of clay, silt, sand, gravel, stones, and boulders; rock fragments of various lithologies are embedded within a finer matrix that can range from clay to sandy loam.

Till plain

An extensive area of level to gently undulating soils underlain predominantly by till and bounded at the distal end by subordinate recessional or end moraines.

Tilth, soil

The physical condition of the soil as related to tillage, seedbed preparation, seedling emergence, and root penetration.

Toeslope

The gently inclined surface at the base of a hillslope. Toeslopes in profile are commonly gentle and linear and are constructional surfaces forming the lower part of a hillslope continuum that grades to valley or closed-depression floors.

Topsoil

The upper part of the soil, which is the most favorable material for plant growth. It is ordinarily rich in organic matter and is used to topdress roadbanks, lawns, and land affected by mining.

Trace elements

Chemical elements, for example, zinc, cobalt, manganese, copper, and iron, in soils in extremely small amounts. They are essential to plant growth.

Tread

The flat to gently sloping, topmost, laterally extensive slope of terraces, flood-plain steps, or other stepped landforms; commonly a recurring part of a series of natural steplike landforms, such as successive stream terraces.

Tuff

A generic term for any consolidated or cemented deposit that is 50 percent or more volcanic ash.
**Upland**

An informal, general term for the higher ground of a region, in contrast with a low-lying adjacent area, such as a valley or plain, or for land at a higher elevation than the flood plain or low stream terrace; land above the footslope zone of the hillslope continuum.

**Valley fill**

The unconsolidated sediment deposited by any agent (water, wind, ice, or mass wasting) so as to fill or partly fill a valley.

**Variegation**

Refers to patterns of contrasting colors assumed to be inherited from the parent material rather than to be the result of poor drainage.

**Varve**

A sedimentary layer or a lamina or sequence of laminae deposited in a body of still water within a year. Specifically, a thin pair of graded glaciolacustrine layers seasonally deposited, usually by meltwater streams, in a glacial lake or other body of still water in front of a glacier.

**Very stony spot (map symbol)**

A spot where 0.1 to 3.0 percent of the soil surface is covered by rock fragments that are more than 10 inches in diameter in areas where the surface of the surrounding soil is covered by less than 0.01 percent stones.

**Water bars**

Smooth, shallow ditches or depressional areas that are excavated at an angle across a sloping road. They are used to reduce the downward velocity of water and divert it off and away from the road surface. Water bars can easily be driven over if constructed properly.

**Weathering**

All physical disintegration, chemical decomposition, and biologically induced changes in rocks or other deposits at or near the earth’s surface by atmospheric or biologic agents or by circulating surface waters but involving essentially no transport of the altered material.

**Well graded**

Refers to soil material consisting of coarse grained particles that are well distributed over a wide range in size or diameter. Such soil normally can be easily increased in density and bearing properties by compaction. Contrasts with poorly graded soil.

**Wet spot (map symbol)**

A somewhat poorly drained to very poorly drained area that is at least two drainage classes wetter than the named soils in the surrounding map unit.
Wilting point (or permanent wilting point)
The moisture content of soil, on an oven-dry basis, at which a plant (specifically a sunflower) wilts so much that it does not recover when placed in a humid, dark chamber.

Windthrow
The uprooting and tipping over of trees by the wind.
APPENDIX E

Drawing of Irrigation Design
Design of Vineyard Irrigation System and Reservoir Enlargement
Matthew M. Moore
BioResource and Agricultural Engineering
BRAE 462
Spring 2013
Advisor: Dr. Daniel Howes

Objective:
- Design a drip irrigation system for wine grapes and a reservoir enlargement for frost protection.

Background:
- 25.3 acre field for Todd Farms in Potter Valley, Ca
- Reservoir has to handle irrigation and frost protection needs

Irrigation Design Parameters:
- Vine Spacing = 8’ by 6’
- Design DU = 0.92
- Water Source = Reservoir
- Soil Type = Russian Loam
- Row Orientation = East to West
- Peak ET Month = May
- Peak ET Value = 4.95 in/month
- Max Hours of Operation = 18 hrs/day 7 days/week
- Field Slope = N/S 0.03% and E/W = 0.02%
- Drip Hose = Netafim Uniram

Reservoir Sizing Constraints:
- Sprinkler Spacing = 48’ by 36’
- Consecutive Nights of Frost = 4
- Hours of Operation = 11 hrs/night
- Sprinkler Type = Nelson R33 Rotator
- Low Temperature = 22°F

<table>
<thead>
<tr>
<th>Reservoir Storage Calculations</th>
<th></th>
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<tbody>
<tr>
<td>GPM/Acre = 99.6</td>
<td></td>
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<tr>
<td>Total Hours of Frost Protection = 44.0 hrs</td>
<td></td>
</tr>
<tr>
<td>Field Size = 25.3 acres</td>
<td></td>
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<tr>
<td>Total Storage Needed = 22.4 acre-ft</td>
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<table>
<thead>
<tr>
<th>Pump TDH Calculations (Drip System)</th>
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</thead>
<tbody>
<tr>
<td>Pressure Required Downstream of Filters = 19.6 PSI</td>
<td></td>
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<tr>
<td>Dirty Media Filter Loss = 7.0 PSI</td>
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<tr>
<td>Emergency Screen Loss = 0.5 PSI</td>
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<tr>
<td>Manifold to Vine Height = 2.8 PSI</td>
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<tr>
<td>Minor Losses = 3.0 PSI</td>
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<tr>
<td>Required Pump TDH = 32.9 PSI</td>
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<tr>
<td>Required Pump TDH = 76.0 ft</td>
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Irrigation Design:
- From the design calculations
  - Peak ET Rate = 0.18 in/day
  - Netafim Uniram Pressure Compensating In-Line Emitters
  - Emitter Flow Rate = 0.260 GPH
  - Hose ID = 0.540”
  - Emitter Spacing = 36”
  - Emitters/Plant = 2
  - Number of Sets = 1
  - Hours of Operation = 12 hrs/day
  - Field Flow Rate = 213 GPM
  - Filtration = Four 30” Sand Media
  - Media = #8 Crushed Granite
  - TDH Required = 75.97’
  - Future DU = 0.96

Reservoir Enlargement:
- Required Flow Rate = 3.95 GPM/sprinkler
- Sprinkler Model = Gold 18 with 9/64” Nozzle
- Flow Rate = 99.6 GPM/Acre

Conclusion/Recommendations:
- Frost protection system will be designed by another company
- Different pump and filter station may be needed
- Recommend a reservoir size of 25 acre-ft
- Design will be presented to grower